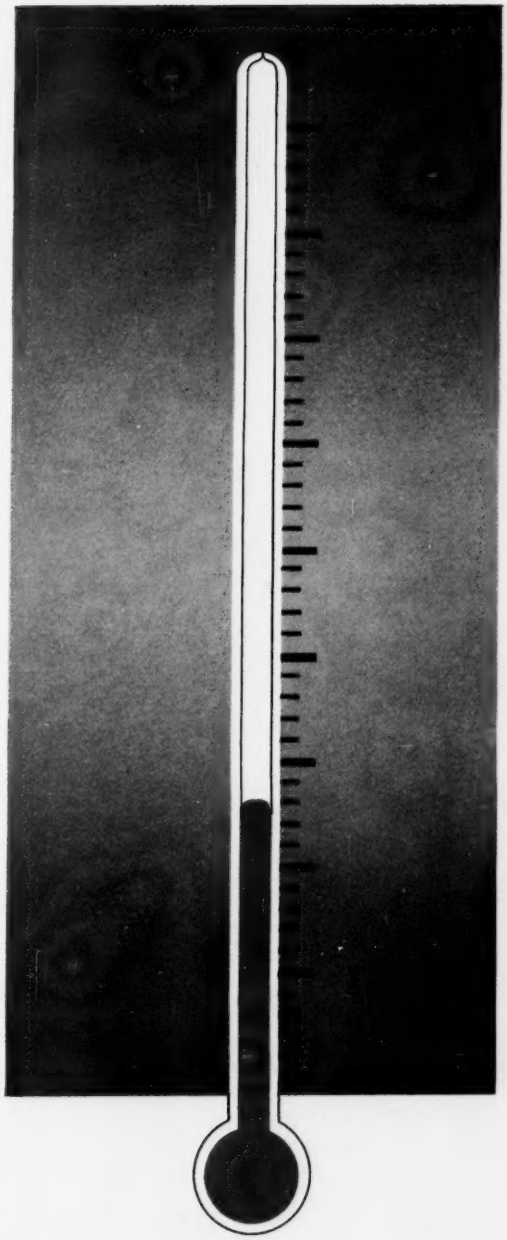
INSTRUMENTS AND CONTROL SYSTEMS

INCLUDING: JOURNAL OF THE SCMA • PRECISION MEASUREMENTS ASSOCIATION • SIMULATION COUNCIL NEWSLETTER



MAY 1961

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NOR Addition 864
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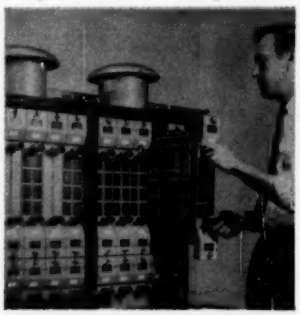
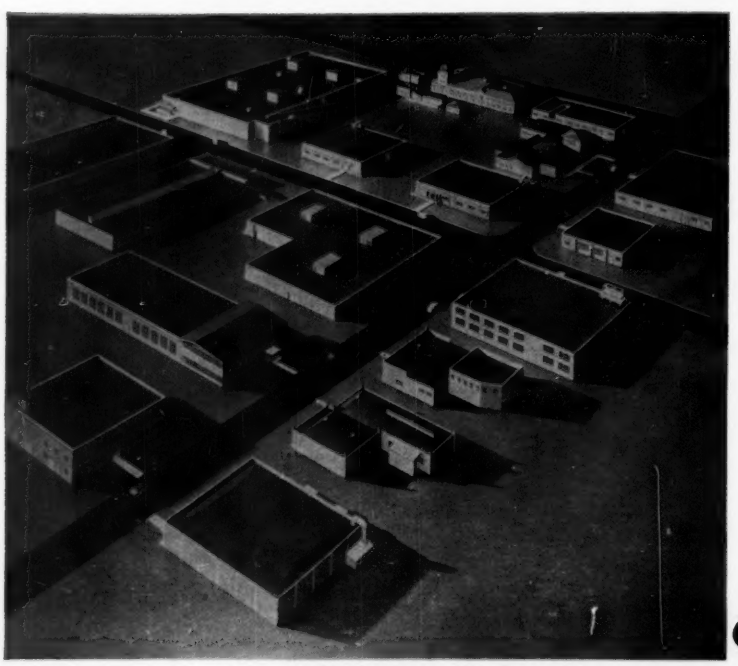
LIBRASCOPE COMPUTER FACILITIES

Shown below is a composite view of Librascope's facilities where a variety of computer systems are currently in different stages of design and production. Some are strategically involved with national defense...others deal with business and industrial process control. Each is uniquely designed to answer a particular need. The success of these systems illustrates the value of Librascope's engineering philosophy: A decentralized organization of specialized project teams responsible for assignments from concept to delivery...and backed up by excellent research, service, and production facilities. For your computer requirements, call on the company whose breadth of diversification in computer technology is unsurpassed. ■ Librascope Division, General Precision, Inc., 808 Western Avenue, Glendale, Calif. For career opportunities write to John Schmidt, Engineering Employment. ■



computers that pace man's expanding mind



GP

CIRCLE 1 ON READER-SERVICE CARD

LEWIS

RESISTANCE THERMOMETER AND ACCESSORIES

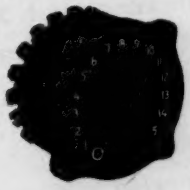
The Model 62 RT4F Resistance Thermometer is a sturdy, easy to read instrument with a six inch hand drawn scale. It is suitable for use in moving vehicles, is excellent for flight testing or for permanent panel installations. Operated by an ordinary dry cell and calibrated to standard "AN" bulb curves, this instrument is ideal for use with any of the resistance bulbs illustrated below. Other ranges available in °C or °F.

ACCESSORIES — RESISTANCE BULBS AND SWITCHES

Lewis Selector Switches have been used for years in automotive test work as well as in permanent installations. Simple, sturdy construction plus finest materials combine to give long service.

2" SIZE TO 4 POINTS

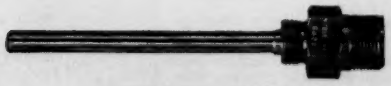
FREE AIR



3" SIZE TO 20 POINTS

THREADED "AN" TYPE

4" SIZE TO 28 POINTS



THREADED "AN" TYPE

BAYONET TYPE FOR CYLINDER HEAD TEMPERATURE

Lewis Resistance Bulbs are adaptable for use with the 62RT4F Resistance Thermometer or with standard aircraft panel indicators. Special purpose bulbs with stem variations or for high temperature applications are available.

We invite inquiries on your temperature measuring problems.

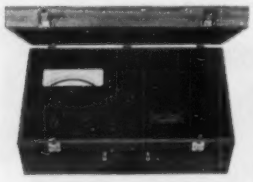
THE LEWIS ENGINEERING CO.

Manufacturers of *Complete* Temperature Measuring Systems for Aircraft

NAUGATUCK, CONNECTICUT

CIRCLE 2 ON READER-SERVICE CARD

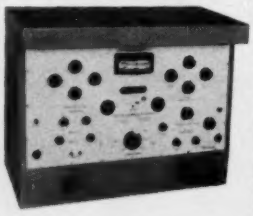
NEW! AC/DC TRANSFER STANDARD



Model FLH — Portable AC/DC difference tester ideally suited for the certification of other transfer standards, or when used with precision DC potentiometers, for the high accuracy measurement of AC voltages. Maximum frequency influence ±.05% to 50 kc. Furnished with NBS correction figures to a certified accuracy of ±.01%. Multipliers used are selected for superior performance over a wide frequency range. Long term stability is not a factor in over-all accuracy.

Ranges: 1.5-3/7.5/15/30/75/150/300/750 V. (Nominal overloads of 50% will not affect operation and, therefore, 750 V range may be used for 1000 V measurements.
Sensitivity: 100 Ω/V
Resolution: .005%

NEW! AC/DC CALIBRATION CONSOLE



Model LTC-1 — Second edition in a series of high accuracy test consoles. Features additional advantages of automatic overload protection and packaging in an aluminum shielded case. The **only** instrument with **all** the standout specifications listed below:
Accuracy: ±.05% of reading DC to 25kc
Current Range: 1 ma to 11.11 amperes
Voltage Range: .5 v to 1111 V
Readout: Directly in "% Error" or in actual figures.
Self contained for one-man operation.

Model LT-PS-1 is a low distortion (.1%), highly stable (±.01%), variable frequency (20 cps-20 kc) power supply for use with LTC.

NEW! AC/DC POLYRANGER

Model UX — Versatile 51 range portable electrical indicating instrument with increased scale resolution and long term performance reliability. Features AC expanded scale, 1000% automatic overload protection and a completely self contained "Self Checking" system. Diamond Pivoted of course!
DC Ranges: 5/10/20/50/100/200/500 mv; 1/2/5/10/20/50/100/200/500/1000 v; .2/.5/1/2/5/10/20/50/100/200/500 ma; 1/2/5 amps.
AC Ranges: .5/1/2/5/10/20/50/100/200/500/1000 v; 10/20/50/100/200/500 ma; 1/2/5 amps.
Accuracy: DC .5%; AC .75% to 5 kc on voltage and 15 kc on current.
Sensitivity: DC 5000 Ω/v; AC 100 Ω/v.

NEW! POCKETPOT

Model PC—Miniature DC potentiometer for use as an infinite impedance calibrator and measuring instrument. Self contained reference source, galvanometer and direct "in line" dial readout. Available with Model PC-1 volt-amp-milliampere "plug in" range extension unit of same size. Single leather carrying case for both items.

Accuracy: ±.05% of reading
Range: .01 —5.09 V
Range Extension Unit: 5/50/500 V (500 Ω/v); .5/5/50/500 ma, 1 amp. Accuracy ±.05%
Resolution: .01 V
Size: 9" x 4¼" x 1¾" each unit

SENSITIVE RESEARCH INSTRUMENT CORPORATION • NEW ROCHELLE, N. Y.

NEW! FREQUENCY SELECTIVE AMPLIFIER

Commander Type 5212M — Null-detector for use with AC bridges, potentiometers and other such devices. Continuous frequency coverage from 10 cps—10 kc or 20 cps—20 kc. 85 to 100 db amplification. Equivalent Q,30. Hum and noise 1.5 μv maximum. Input impedance 100,000 ohms shunted by 10 pF. Output impedance 400 ohms.

NEW! VARIABLE STANDARD INDUCTOR

Commander Types 9001, 9011 and 9111 precision mutual inductor with ranges of .1 μh—1.111 mh, 1 μh—11.11 mh and 10 μh — to 111.1 mh. Low capacitance construction features stranded silk-covered copper wire, wound on marble formers. Accuracy ±.02% to ±.05% DC to 1000 cps.

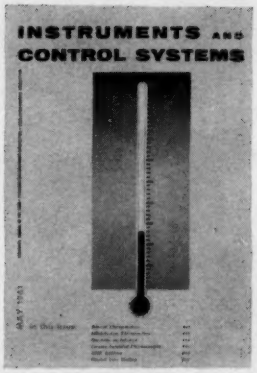
Primary & Reference Standard Electrical Instruments and Accessories

DC POTENTIOMETERS—6 figure instruments; Type 9144 Dauphinee ±.001% accuracy.
EXPANDED SCALE INCREMETER—Model INCRE DC volt-milliamp meter; 70" scale length; ±.05% accuracy.
STANDARD CELL ENCLOSURE—Type 9152 holds 4 saturated cells; controlled to ±.01°C.
SATURATED STANDARD CELLS—Type 4305; certifiable to ±.0001%.
AC-DC VOLT-AMP-MA METER—Model THACH-5X, ranges up to 5a and 1000 v; Self Checking; ±.2% accuracy; ±.1% at multicheck points.
AC-DC POWER SUPPLY—Overload Protected Model THACH-PS for use with Model THACH.
GALVANOMETERS AND GALV. AMPLIFIER—Types SR21 and 5214; sensitivity up to 1750 mm/μv.
FLUXMETERS—Model FM multirange or FS single range; ±.5% accuracy.
PORTABLE OR PANEL AC-DC METERS—Model N volt-amp-milliamp. meters; 6.1" scale length; ±.5% accuracy. Model C, CEW-7 .25% accuracy.
OVERLOAD PROTECTED POLYRANGER—Model 2-AP withstands up to 5000% overload; ±.75% accuracy.
PRECISION CHOPPERS—Type 9744; thermal emf's less than .01μv.; Types 9742A/3 miniature choppers.
STANDARD VOLT RATIO BOXES — Type 9700A per NBS RP1419; accuracy ±.005%; type 4281 ±.02%.
ELECTROSTATIC VOLTMETERS—Model ESH to 100 kv, $10^{14}\Omega$ input impedance; Model ESD to 6 kv; ±1% accuracy.
DC VOLTAGE REFERENCE—Model STV 1.0000 and 1.0185 v.; Zener stabilized to ±.01% accuracy.
WATTMETERS—Models DW, DLW and PDW single and polyphase down to 20% p.f.; ±.25% to ±.75% accuracy.
THERMOCOUPLE INSTRUMENTS — AC-DC voltage to 10 mc; Current to 20 mc; ±.5% to 1% accuracy.
MAGNETIC TESTING SETS—Models MAT and COL for testing per ASTM specifications.
RF VOLTMETER CALIBRATOR—Model RFVC Self Checking; .01/.1/1/3 v; ±.3% accuracy ±.2% freq. influence.

Portable and Panel AC and DC instruments for the measurement of current, voltage, power, power factor, frequency, temperature and magnetic quantities.

CIRCLE 3 ON READER-SERVICE CARD

INSTRUMENTS AND CONTROL SYSTEMS



Liquid-in-glass thermometer highlights subject for major emphasis this month—temperature measurement. This continues our extensive series on this subject.

FEATURE ARTICLES

Bimetal Thermometers 841

E. R. KEBBON—Bimetal thermometers feature simplicity, ruggedness and economy.

Liquid-In-Glass Thermometers 846

JAMES F. SWINDELLS—The liquid-in-glass thermometer is the most widely-used temperature instrument but it is not foolproof. The user must understand its limitations and calibration procedures.

Temperature Measurement by Filled System 849

ROBERT C. NELSON—Filled thermometers perform the bulk of industrial temperature measurements. Here are their features.

The Ten Most-Asked Questions on Infrared 854

BURTON BERNARD—Does infrared vary with temperature? What is emissivity? Is there a limit to the range of an infrared thermometer?

Ceramic-Insulated Thermocouples 856

L. SCADRON—New advances reopen the question of single versus multiple-pass drawing technique. Manufacturers make conflicting claims.

Swaged MgO Thermocouples 858

EARLE C. SMITH—A supplier's specification for metal-sheathed ceramic-insulated thermocouples, plus comments.

Thermoelectric Properties of Rhodium-Platinum Alloys 861

A. S. DARLING—A review of the thermoelectric properties and behavior of the various compositions of rhodium-platinum alloys.

Thermocouple Loading 863

W. E. BOSTWICK—An exercise in impedance matching

NOR Addition 864

ERNEST P. CROZIER, JR.—Eight NOR elements perform binary addition. Another installment in our series on symbolic logic

Fluxlok High-Speed Core Memory 866

ROBERT M. TILLMAN—A random-access high-speed nondestructive-read memory using ferrite cores.

Process Control Systems 870

Internal reflux computer for petroleum fractionator; size preparation controlled by temperature and "bubbler" level controller; level measurement in closed vessel using purge (bubble) technique; x-ray sheet gaging and classifying system; continuous automatic metering of solid materials.

Digital Positioning 872

T. GIZESKI—Sixteen solenoids can provide positioning to 1 part in 2^{16}; lever system permits use of solenoids of similar displacement.

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INSTRUMENTS AND CONTROL SYSTEMS

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MAY 1961

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W. E. BOSTWICK and H. C. McDONALD—The equation for the output of a strain-gage bridge

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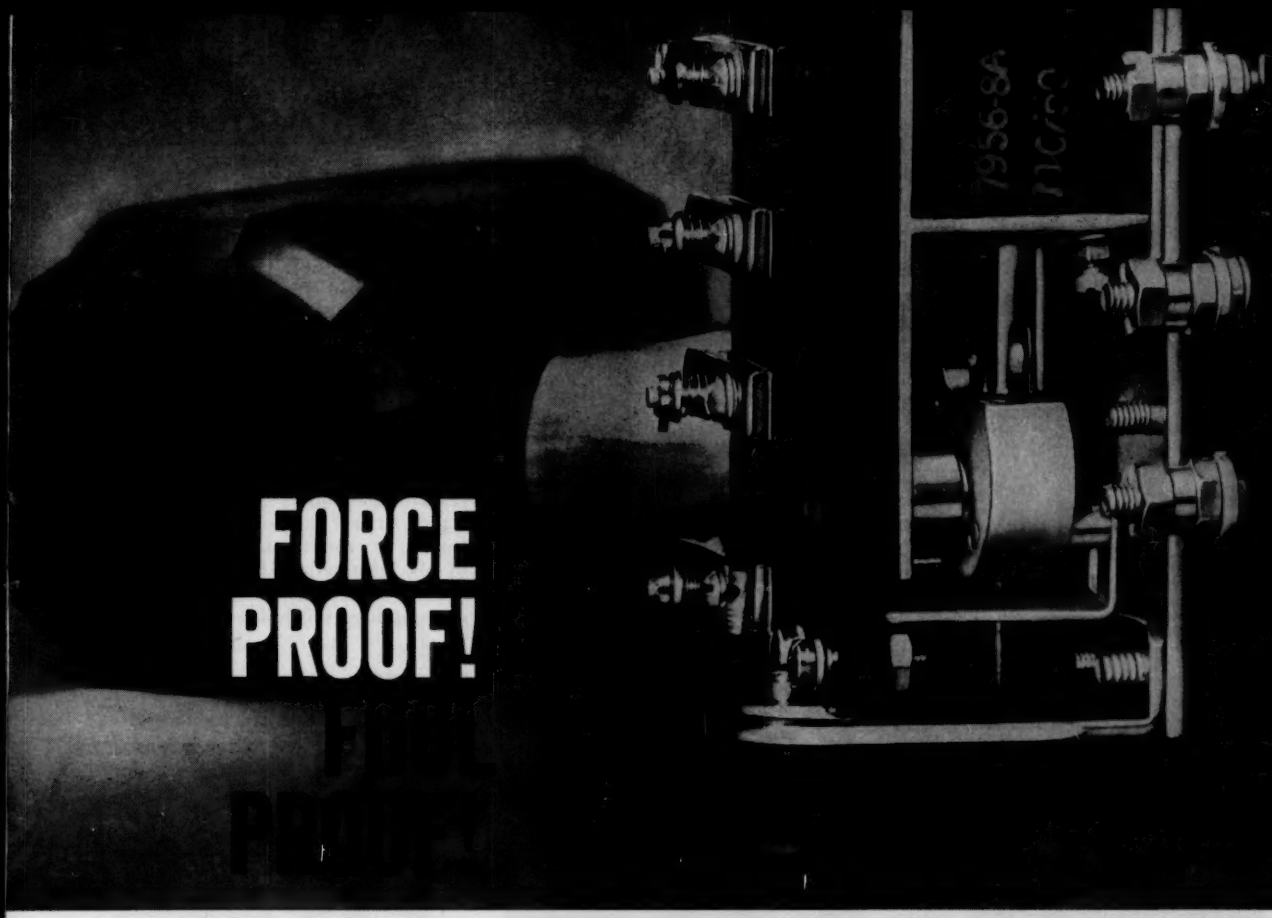
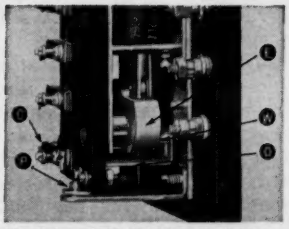
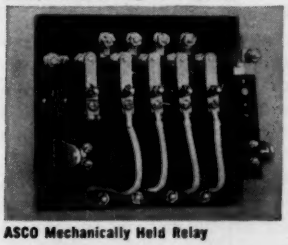


FORCE PROOF!



The Unique ASCO Mechanically Held Movement When the solenoid is energized, eccentric cam E is rotated. Weight drive pin W causes movement of operating lever D. Lever D (connected to the contact finger block) rotates on pivot pin P and contacts such as C are opened or closed.

With the solenoid de-energized, the entire mechanism is firmly locked in place by the angular position of the linkages—no springs, latches, or semipermanent magnets required!



ASCO Mechanically Held Relay

even **brute force** will not release the ingenious locking mechanism of **ASCO MECHANICALLY HELD RELAYS**

We don't recommend using force, of course; we just want to emphasize that, short of deliberate destruction of the linkages, only one action can release this powerful locking mechanism and change relay contact position. That action is normal energization of the solenoid coil. Nothing else will alter the angular relation of the linkages, which maintains positive contact pressure despite vibration, gravity, or control circuit failure.

The unique mechanical movement is the heart of any ASCO Mechanically Held Switch or Relay. At the instant of operation, a momentary surge of electrical power retracts the solenoid core to rotate a cam. Momentum carries the cam beyond dead center, and spring-loading completes the core-return stroke to relock the relay in the new position. Linkage action is the same whether contacts are opening or closing; thus the relay is power-driven in both directions.

Design simplicity, typified by the single-solenoid coil mechanism, and rugged, compact construction are characteristic of ASCO Mechanically Held Relays. Complex and less dependable elements such as hooks, latches, semipermanent magnets, or gravity-operated devices are not used. These ASCO relays operate in any position; without AC hum or chatter, and without derating for enclosure.

The extensive ASCO line includes a Mechanically Held Relay to meet your requirements precisely; single pole or in combinations of 24 poles; single or double throw; 10 and 25 amperes; to 250 volts DC, 600 volts AC.

Send for Relay Catalog 57-S4, which shows you how to select the optimum relay for your specific needs.

ASCO Electromagnetic Control

ASCO

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for gage, absolute and differential pressure measurement

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Check these features of the P713:

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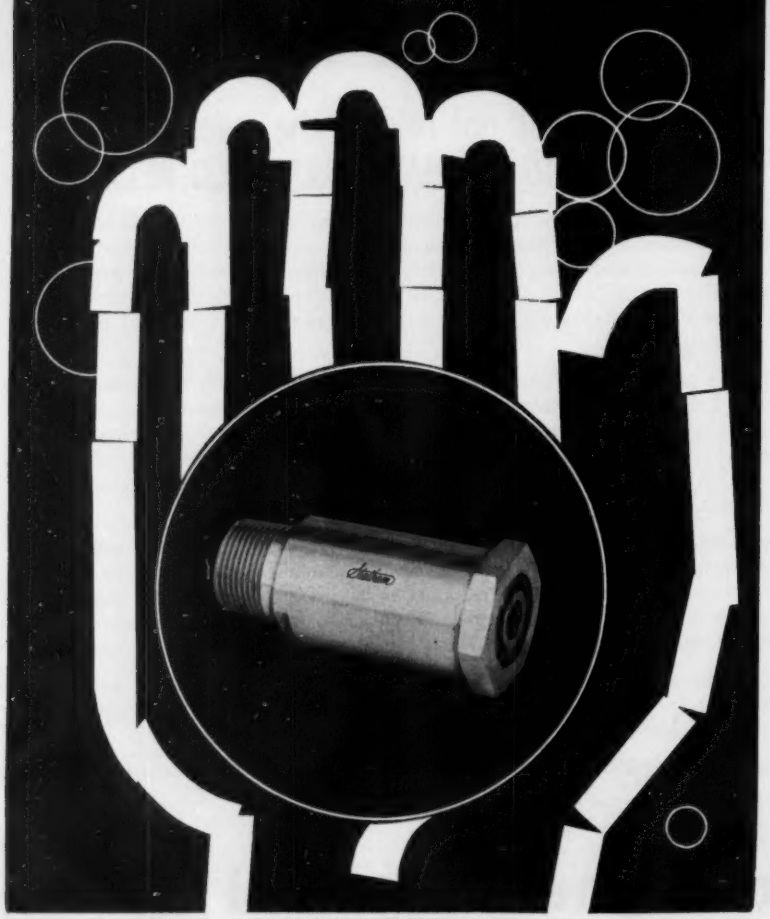
- Compact size
- High accuracy calibration accomplished electrically at the control room
- Ultimate in ruggedness, simplicity and reliability



CIRCLE 6 ON READER-SERVICE CARD

LETTERS TO THE EDITOR

Editor, I&CS:

In your February issue I was greatly surprised to see, in "Trends", that Canada has now adopted the British monetary system of pounds, shillings, and pence, particularly since our Government has not informed us of the change. Such appalling ignorance on the part of your editorial staff makes one doubt the accuracy of your survey of the Canadian instrument market. Obviously, the reporter assigned to this task did not take the trouble to cross the border in search of his information. I might suggest that we have many pleasant vacation spots up here which he might do well to consider as he takes his "rest-cure".

R. E. Bark
Lachine, QUEBEC

The survey was not ours—it was a British-made survey, abstracted for our readers. But the rest cure sounds fine!

Editor, I&CS:

Comparing your magazine *Instruments and Control Systems* and (another), friends of mine and myself seem to prefer your magazine.

The subscription rates are the same, except you didn't quote the multiple one year rate. Please let me know what it is, so if a similar economy can be realized, I shall send you by return mail seventeen addresses and a money order for the total amount.

Emeric S. Kozary
Hamilton, Ontario, CANADA

Editor, I&CS:

Re: Volume 34, No. 2. of your February 61 issue of your *Instruments and Control* magazine.

The regular feature writer who calls himself "Panhandle Pete" in the reference magazine has either been the unwitting tool of a clever communist writer or is actually a prime suspect himself, if the idealogical expressions under "Computer conclusions" in his WESCO! Symbolic-logic Computer article may be considered as an index of his usual material.

Notice under his "Problem 1" how he cleverly emphasizes a communist objective to influence public opinion in the Free World toward disarmament, so that the Soviet can continue

their aggressive policies unhindered:

Problem 1: $(A \cdot B \cdot C) \vee \overline{A} \cdot B \vee \overline{C} \cdot A$

A. Nations often go to war.
B. They usually use the most powerful weapons on hand.
C. Nuclear weapons can destroy civilization.

Computer Conclusion: QUICK WAY TO DESTROY CIVILIZATION IS TO ARM MANY NATIONS WITH NUCLEAR WEAPONS.

In problem 2. he continues the communist line by making comments derogatory to the United States.

In problem 3. he casts the shadow of doubt on the value of "clean nuclear bombs."

In problem 4. he again uses a theme derogatory to the United States. In addition he casts doubt upon the efficiency and quality of our military equipment. Obviously an attempt to undermine the moral (sic) of Americans:

Problem 4:

$(A \vee B) \cdot (\overline{B} \cdot C \vee A) \cdot (\overline{A} \vee C) \cdot (D \vee \overline{C}) \cdot E \vee F$

A. Educated technical manpower is a national asset for years.
B. Quality teachers are essential to obtain educated technical manpower.
C. Low pay for teachers causes good teachers to leave profession.
D. Military equipment becomes obsolete quickly.
E. Average pay for teachers in USA is $6200.
F. Average pay for missile engineers in USA is $12500.

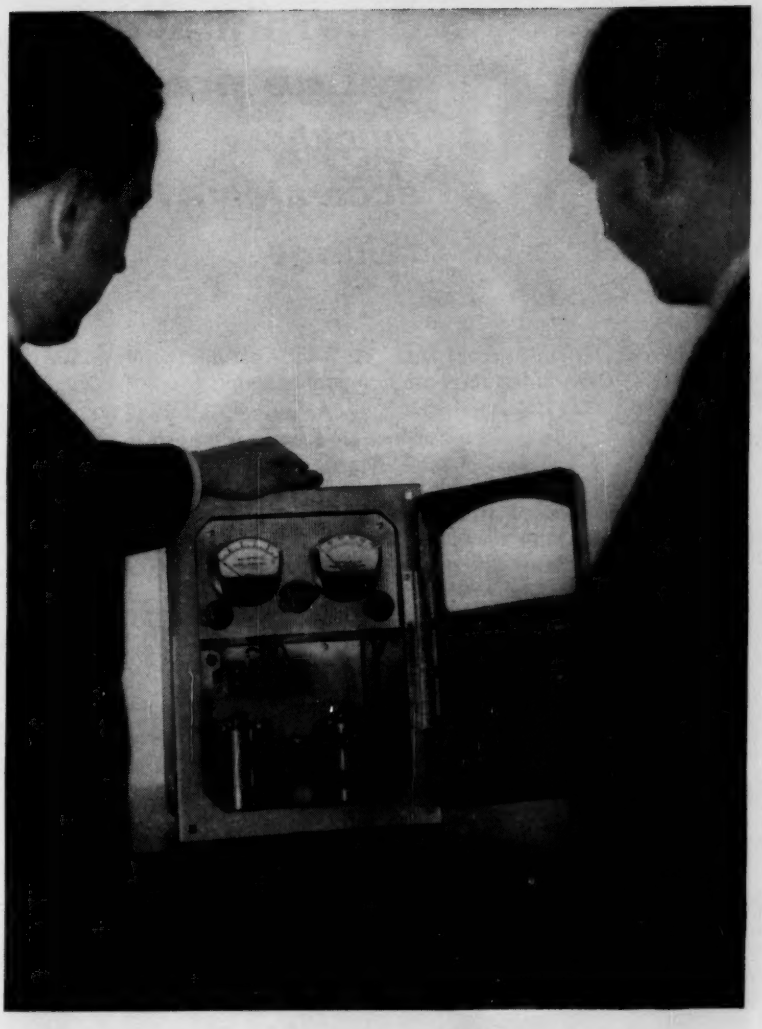
Computer Conclusion: USA TEACHER MIGRATION TO MISSILE JOBS WILL RESULT IN DECLINE IN TECHNICAL MANPOWER WHILE USA WASTES SUBSTANCE ON RAPIDLY OBSOLESCENT MILITARY EQUIPMENT. NATION THAT SPENDS MOST ON EDUCATION WILL END UP MOST POWERFUL AND PROSPEROUS.

In problem 5. The comment is inflammatory to Labor and a clumsy attempt to create Labor/Management and Labor/Government friction.

In problem 6. Derogatory to the United States.

Problem 6:

A. Forty billion barrels of foods are rotting in USA storage bins.
B. People are hungry all over the world.
C. Billions of dollars are being given to USA farmers not to grow more food.
D. USA Government is spending billions buying food to keep prices high.
E. Storage costs are millions of dollars per day.
F. Inflation causes misery to hungry unemployed and low fixed-income groups.
G. There are more than 4 million USA unemployed.
H. It is immoral and heartless to deny food to the hungry.
I. It is stupid and ridiculous to cause inflation.



"continuous analysis of the dissolved oxygen in boiler feedwater?"

"Sure . . . and without any scrubbers, chemicals or tanks of gas."

This is the Hays Dissolved Oxygen Analyzer to measure in the parts per billion range. Built-in calibration check . . . simple construction . . . low maintenance . . . accurate—full-scale range as low as 0 to 20 ppb . . . unaffected by DO scavengers. Reduce your corrosion problems caused by dissolved oxygen in your feedwater.

for further details write for Bulletin B625

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READ differential or gauge pressure *quickly... accurately... reliably*

Wallace & Tiernan Aneroid Dial Indicators give you fast response, high sensitivity, reliable accuracy.

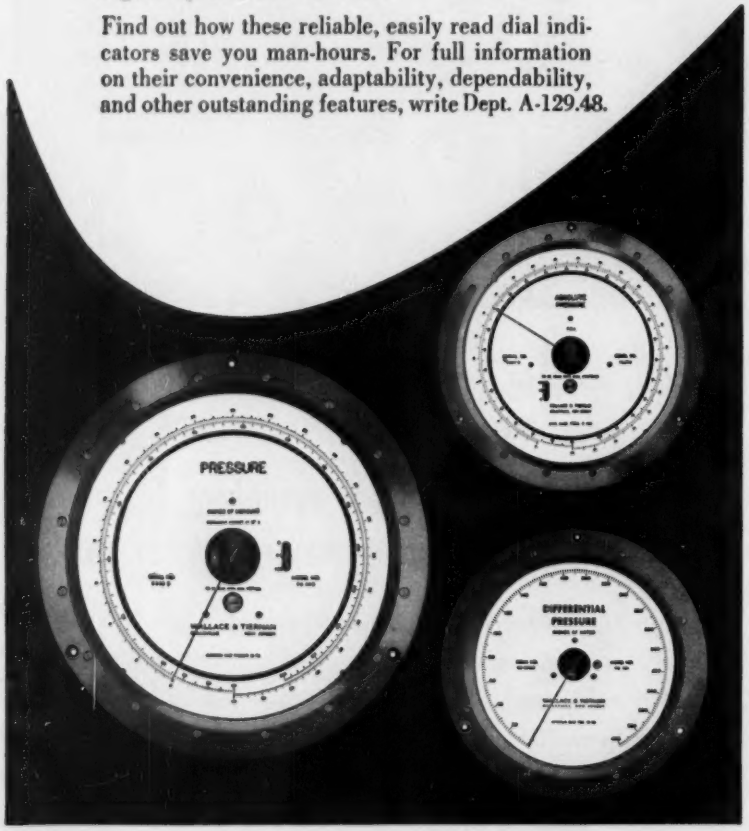
Whether you're in testing, manufacture, or research, there's a W&T Dial Indicator that's ideal over a wide range of differential or gauge pressures.

A W&T Aneroid Dial Indicator guarantees you:

- ★ Accuracy 0.1% to 0.33%
- ★ Sensitivity 0.01% to 0.2%
- ★ Range 0-10″ H_2O to 0-500 p.s.i.g.
- ★ Light weight, small size
- ★ Custom-calibrated dial
- ★ No corrections

W&T Aneroid Dial Indicators are also furnished as compound gauges with zero center for measuring both pressure and vacuum.

Find out how these reliable, easily read dial indicators save you man-hours. For full information on their convenience, adaptability, dependability, and other outstanding features, write Dept. A-129.48.



WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CIRCLE 8 ON READER-SERVICE CARD

J. It is insane to purchase food only to have it rot in storage.

$$A \vee \overline{C} \vee D \vee (\overline{A} \vee B) \vee \overline{C} \cdot D \vee (\overline{E} \vee A) \vee (\overline{G} \vee C) \vee (\overline{B} \vee A) \vee I \cdot \overline{J} \cdot H$$

Conclusion. USA AGRICULTURAL POLICY IS HEARTLESS, RIDICULOUS, SELF-DEFEATING, INSANE, IMMORAL, STUPID, RIDICULOUS . . . . . .

WATCH THIS GUY!

P. W. Slocum
Santa Ana, Calif.

Copy to: J. Edgar Hoover, Federal Bureau of Investigation, Washington, D. C.

Since we do not want the FBI after our editorial staff, we have destroyed the computer—especially after it refused to sign a loyalty oath.

Panhandle Pete:

Congratulations on your fine column in the February 1961 issue. It's high time people came right out and laid the facts on the line. You'll probably get a few kicks—but ignore them. You did right, and you did well.

M. Underwood
Monsanto Chemical Co.
Springfield, Mass.

Panhandle Pete:

In your February issue on pages 224 and 225 there was a report on the Symbolic-Logic Computer, copies of which I should like to send to friends of mine.

Winthrop C. Swain
Draper, Sears & Co.
Boston, Mass.

Editor, I&CS:

I sent the copy of Panhandle Pete's machine for data retrieval and writing prayers to some friends at Oak Ridge National Laboratory and it seems to have gone over the entire plant and caused quite a laugh. But I lost my copy. If you have another I would like to have it.

Robert H. Gentry, M.D.
Knoxville, Tennessee

Editor, I&CS:

Your editorial entitled "The Engineering Shortage", page 61, January, 1961 issue is much appreciated.

All too often the Engineer's views are ignored in the many editorials and speeches made on the subject of Engineers. It is therefore appreciated when an engineering journal of the caliber of *Instruments and Control*

Systems leans a bit towards the side of the Engineer.

For some reason there is sufficient glamour attached to a talk or an article expounding on the shortage of Engineers to ensure an audience. The arguments put forward are generally based on the following premises: (1) There should be a certain number of Engineers per million people. (2) The number of Russian Engineering graduates per year.

There cannot be a shortage of Engineers as long as Engineers are utilized to perform repetitious tasks.

Engineers must support and be active in a strong Professional Engineer's Association. This Association should speak up and repudiate false statements concerning the Profession. It should police the Profession to (1) ensure that Engineers, in all phases of endeavor, live up to an Engineering code of ethics and (2) prevent diluting and downgrading the Profession through the use of unqualified people. Unfortunately, many Engineers feel that they can continually derive benefit from the Profession without assisting in the betterment of it.

W. W. Cliffe, P. Eng.
Canadian General Electric
Peterborough, Ontario

Editor, I&CS:

Your *Temperature Measurement and Control Handbook* covers a number of points that operating technicians and even engineers are not consciously aware of when using temperature as a processing parameter. One of the problems we constantly run into is this lack of critical appraisal of temperature measuring systems by operating personnel. Any dial indicating °F is usually viewed with something akin to reverence. Your *Handbook* is being circulated to our research people as it should help to correct this situation.

D. L. Burk
Allegheny Ludlum Steel Corp.
Brackenridge, Penna.

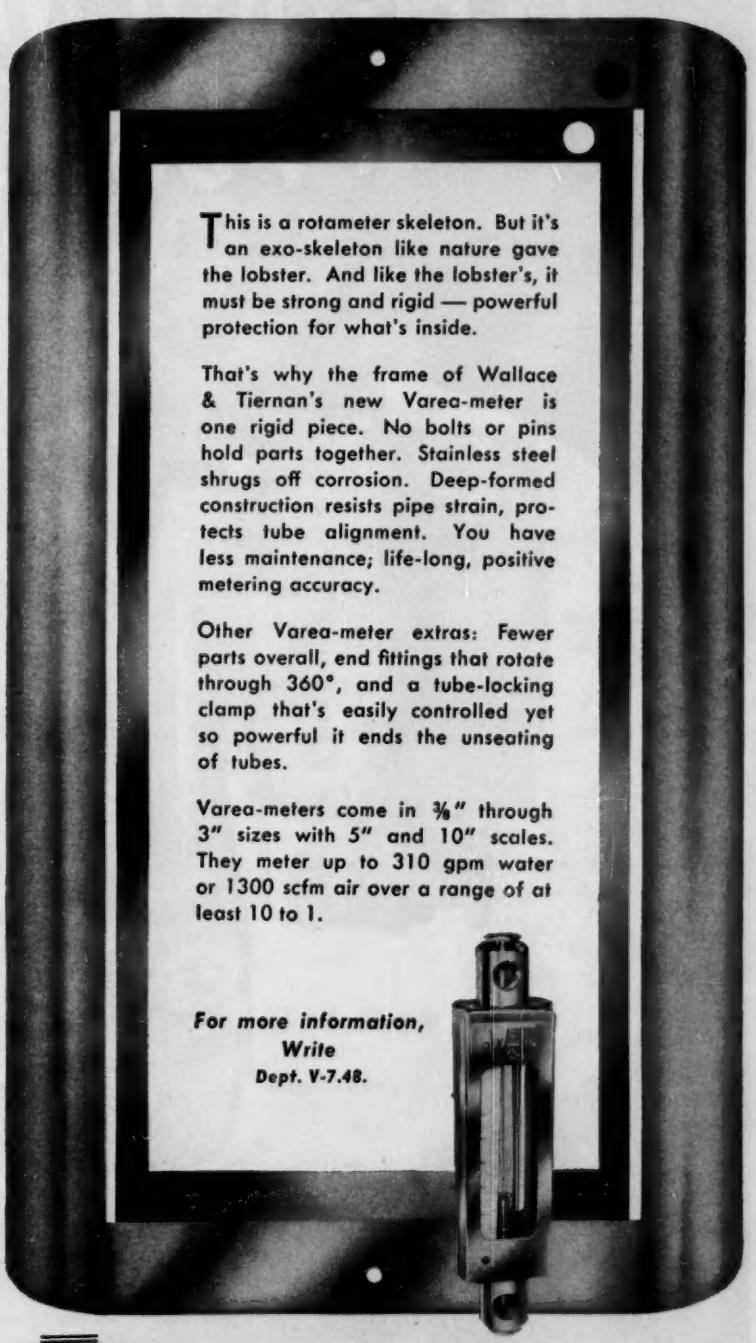
Editor, I&CS:

Your Reader Inquiry service is an excellent idea to put the designer in contact with the right manufacturer.

Edward Blom
Instrument Design Engineer
AiResearch Manufacturing Co.
Div. of Garrett Corp.
Los Angeles 45, Calif.

Reader Inquiries are on page 818.

THE Anatomy OF A ROTAMETER



This is a rotameter skeleton. But it's an exo-skeleton like nature gave the lobster. And like the lobster's, it must be strong and rigid — powerful protection for what's inside.

That's why the frame of Wallace & Tiernan's new Varea-meter is one rigid piece. No bolts or pins hold parts together. Stainless steel shrugs off corrosion. Deep-formed construction resists pipe strain, protects tube alignment. You have less maintenance; life-long, positive metering accuracy.

Other Varea-meter extras: Fewer parts overall, end fittings that rotate through 360°, and a tube-locking clamp that's easily controlled yet so powerful it ends the unseating of tubes.

Varea-meters come in ⅜" through 3" sizes with 5" and 10" scales. They meter up to 310 gpm water or 1300 scfm air over a range of at least 10 to 1.

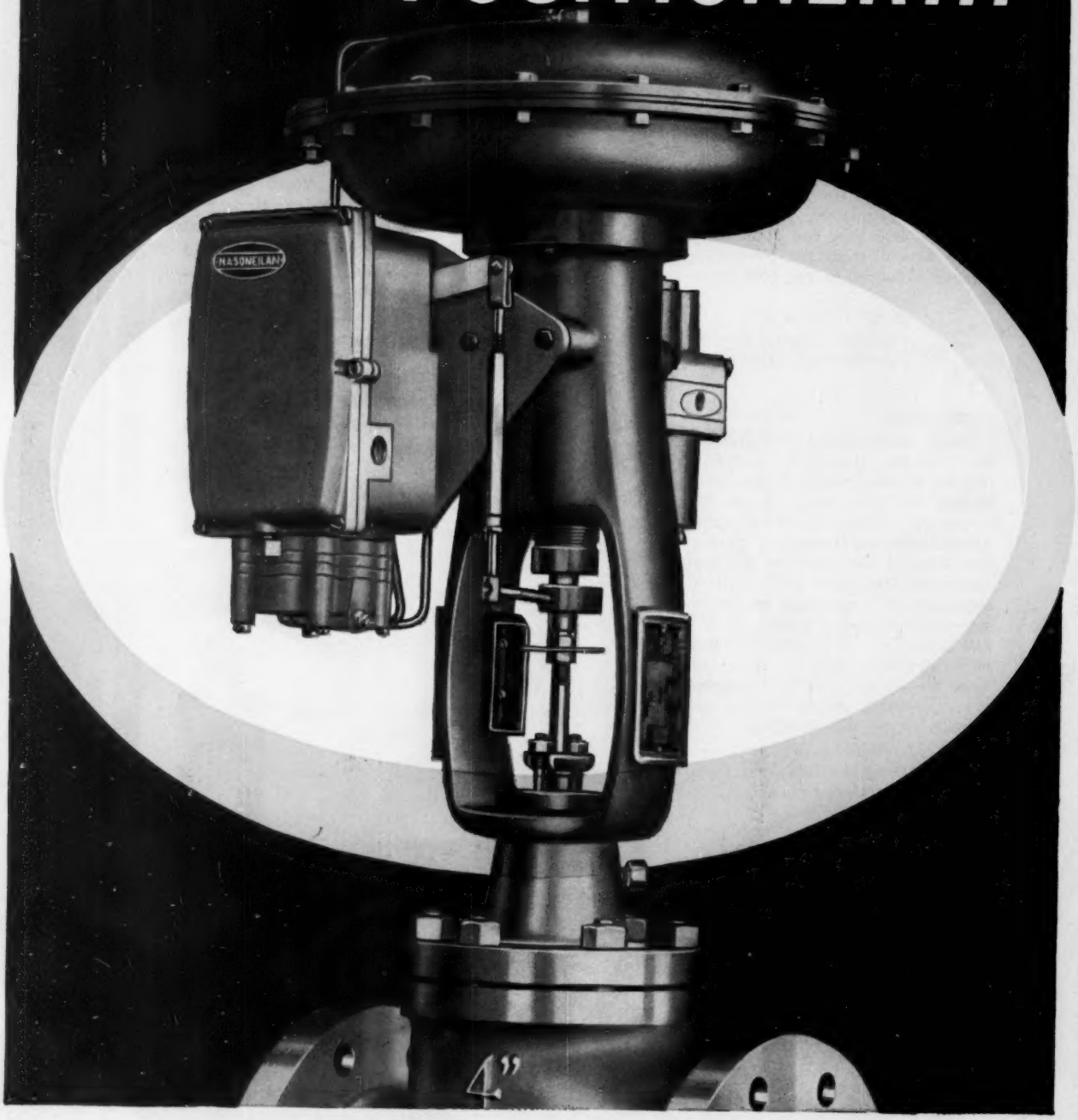
For more information, Write
Dept. V-7.48.

WALLACE & TIERNAN INC.
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CIRCLE 9 ON READER-SERVICE CARD

MASONEILAN

ELECTROPNEUMATIC POSITIONER...



Arranges Happy Marriage

Between Electronic Controller and Pneumatic Control Valve

The advantages of the electronic controller can now be mated to the superior power and smooth throttling action of the pneumatic control valve by means of Masoneilan Model 8010 Electropneumatic Positioner — the most advanced device available for converting electric output signal to pneumatic positioner output.

Fidelity of positioning is assured because Model 8010 is a true positioner providing *direct* comparison of valve stem position with controller output signal, resulting in dynamic response and accuracy *not possible with any combination of transducer and positioner.*

Compatibility with any presently available electronic controller is obtainable because design provides for adaptability to all usual controller output signals.

Character of the design results in high open-loop gain and closed-loop stability. Balanced beam permits installation of the valve in any position without calibration shift.

You Are Invited to join the growing number of users who recognize the superior merits of Masoneilan Electropneumatic Positioners. The first step — obtain complete information. Get in touch with any Mason-Neilan office or representative; or write direct to

MASONEILAN

Products that work for your profit

MASON-NEILAN

Division of Worthington Corporation

55 Nahatan Street, Norwood, Massachusetts

DESIGN FEATURES

- Extra large stabilized magnet, plus efficient magnetic circuit, provides high-force changes.
- External stroke adjustment accessible without removal of cover — no exposure of electric wiring.
- High capacity relay for fast stroking speeds. Relay may be mounted in any one of four positions to facilitate piping.
- Balanced beam permits installation of valve in any position without shift in calibration.
- Available for 3-15 psi or 6-30 psi valve spring ranges and for split-ranging. Standard stroke ranges ⅜" – 3" and 2" – 4". Others available.
- Available with direct or reverse action and for direct or reverse actuators.
- Explosion-proof construction meets requirements of Class I, Division I, Group D.

PERFORMANCE DATA

Open-loop Gain* — approx. 100

Linearity—within ±1% of full stroke

Repeatability — within 0.2%

Load Sensitivity — output pressure change of 1.2 psi per 0.1% of full stroke offset

Supply Pressure Effect — ±1% of full stroke for ±5 psi change from 20 psi

*Defined as $\frac{\%\text{ of full stroke}}{\%\text{ of full input range}}$

CIRCLE 10 ON READER-SERVICE CARD

HOW FAR... AND HOW FAST...

can you use computer control *profitably?*

BAILEY 700 SYSTEMS CAN HELP YOU DETERMINE THIS—ONE STEP AT A TIME

Can computer control be used—profitably—in your process operations?

Where and how?

The answer often lies in intermediate stages of improvement in sensing, measuring, controlling, computing.

Bailey engineers can help you determine and prove — one step at a time — how far analog or digital systems can be profitably applied in your operations. Bailey is equipped, by broad experience, to provide single-source responsibility from sensing and measuring instrumentation to complete automation. *Bailey 700 Systems* are installed, in operation, or on order, at locations from coast to coast and throughout the world.

Find out what this Bailey background can offer. Contact your Bailey District Office.

SIX STEPS TO FULL AUTOMATION

Centralize and simplify information display—use analog and digital techniques to clarify information, aid operator understanding, improve reliability of interpretation, and save space.

Extend use of interlocks and limiting circuitry—use digital solid-state components to extend supervisory controls, thereby minimizing effects of human error.

Increase use of automatic sub-loops—simplify and standardize the starting, controlling, and stopping of major plant components and sub-systems.

Extend on-line controls—integrate sub-loops, interlocks, and limiting controls with conventional controls to secure automatic operation over full range, once unit is on the line.

Provide performance monitoring—add computing facilities to provide significant up-to-date calculations for operation improvement and maintenance scheduling.

Integrate all system elements—add start-stop control to provide full automation, the ultimate goal.

G 158-1

INSTRUMENTS, CONTROLS, AND SYSTEMS

BAILEY METER COMPANY

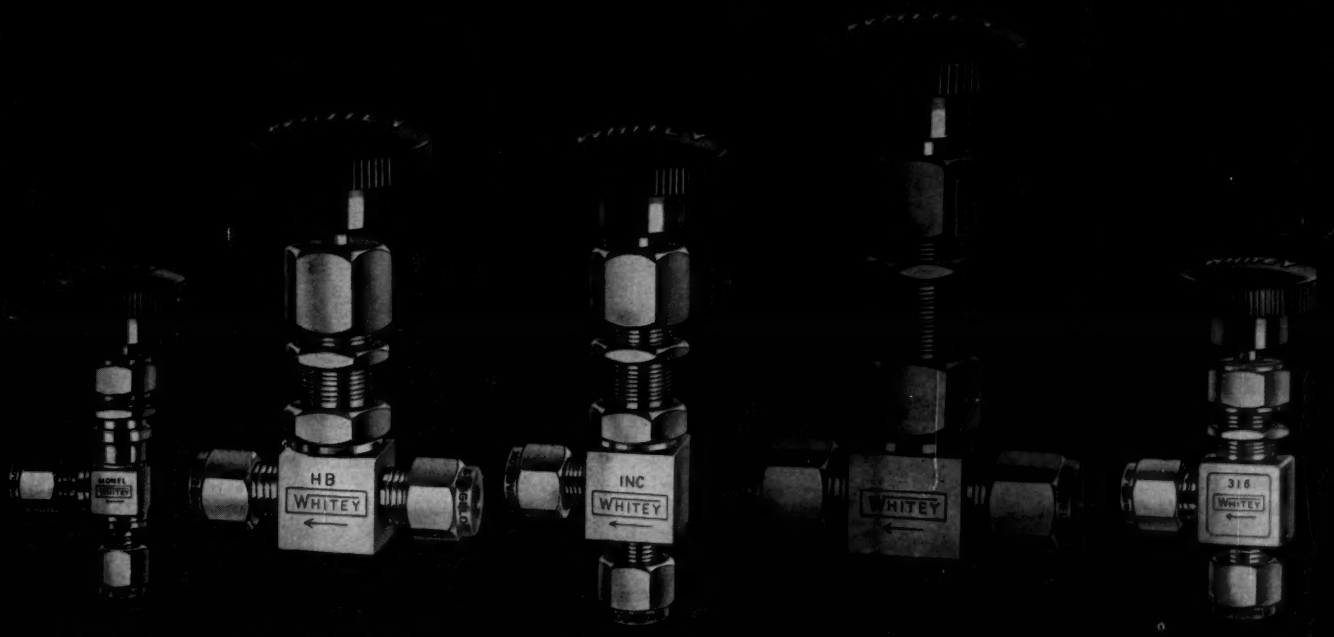
1041 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

CIRCLE 11 ON READER-SERVICE CARD

FOR EXACTING SERVICE WHITEY CONTROL VALVES

for ⅛ through ½ O.D. Tubing feature usual and unusual metals with Swagelok Tube Fitting Connections



• MONEL • HASTELLOY B • INCONEL • BRASS • 316 S.S.

For years, WHITEY RESEARCH TOOL CO. has used exceptional machining and engineering skill to produce valves in new alloys that most manufacturers hesitate to machine. Monel, Hastelloy, Inconel and Nickel require top skill. It is through this manufacturing skill that quality performance is combined with quality appearance to provide precision, leak-tight WHITEY Valves to meet your most exacting system requirements.

WHITEY Valves are available in straight and angle pattern styles with ⅛" through ½" SWAGELOK Tube Fitting connections or ⅛" through ½" male and female pipe connections.

Panel mounting; Teflon* cylinder packing; micro-regulating and non-regulating stems are standard features on all WHITEY Valves. Colored handles, to permit color coding, can be specified when ordering.

Pressure ratings of WHITEY Valves range from 3,000 p.s.i. to 5,000 p.s.i. All WHITEY Valves are available with SWAGELOK Tube Fitting connections for efficient, leakproof installation.

COMPLETE TECHNICAL DATA ON *WHITEY* VALVES AVAILABLE ON REQUEST.

*Dupont Trademark

WHITEY RESEARCH TOOL CO.
5525 MARSHALL STREET
OAKLAND 8, CALIFORNIA

WHITEY TM*

CIRCLE 12 ON READER-SERVICE CARD

A NEW ADDITION TO THE SONAC *LINE*

POSITIVE ULTRASONIC LEVEL CONTROL

The components of Sonac (sensor actual Size)

Now, two new ultrasonic sensors, especially for level control have been added to the Delavan line of SONAC sensing and switching devices.

The single sensor system is recommended for liquid level control and the double sensor system for dry level control.

Control is maintained by installing the SONAC sensor through the wall of the vat, bin or hopper. When the oscillation on the face of the sensor is dampened or impeded by the material being sensed, the signal to the control unit changes, activating a relay.

FIG. 1—LIQUID LEVEL (One Sensor)

FIG. 2—DRY LEVEL (Two Sensors)

For level control, SONAC is accurate to .005" and has a response time of 25 milliseconds. Performance of the sensor does not deteriorate with age.

The level control uses to which SONAC can be applied are virtually unlimited. It is not affected by the viscosity*, specific gravity, conductivity, or capacitance of the material being sensed. Temperature or pressure changes of the material do not alter its performance. False signals are eliminated because SONAC may be adjusted so as not to sense steam, foam, or vapors.

*Viscosity may affect response time.

Canadian Representative:

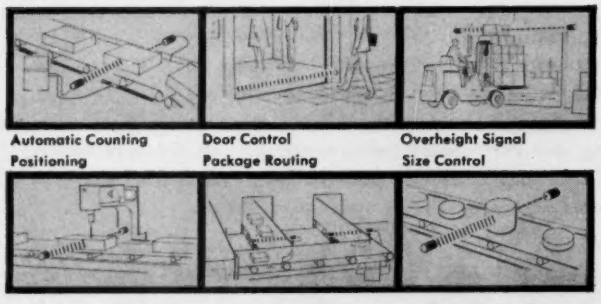
KNOWLES & FOSTER (North America) Ltd.

708 Terminal Bldg., Toronto 1, Ontario, Canada

SONAC is extremely rugged. Sensors are type 304 stainless steel. The electronic components in the sensors are hermetically sealed and will withstand pressures to 2000 psi and temperatures from −425° F. to +450° F. They are immune to shock, vibration or mechanical damage.

The control is a compact unit 5" x 5" x 5" and features transistor circuitry. Power consumption is one watt and the unit will operate in temperature ranges from 40° F. to 135° F.

Here's how SONAC can be used for sensing and switching applications other than level control.



Automatic Counting Positioning | Door Control Package Routing | Overheight Signal Size Control

There are dozens of applications for SONAC *single and double sensor units. Let it go to work for you now, write:*

DELAVAN Manufacturing Company

WEST DES MOINES • IOWA

A

CIRCLE 13 ON READER-SERVICE CARD

The LGP-30 Electronic Computer is designed to stop the juggling of figures —and start the creating of profits.

The Royal Precision LGP-30 can solve routine and theoretical mathematical problems 30 times faster than any man—yet rents for little more than the salary of an additional engineer.

It is simple to program and operate, so no special programmer is needed. An engineer can use it himself. It requires no air-conditioning or costly installation. It plugs into any 110-volt AC wall outlet. It is mobile, so it rolls anywhere. It is desk-size, so it requires little room.

This means that the Royal Precision LGP-30 is ready to go to work to help your company create new products—and fresh profits—the very same day it is delivered. Can you wonder that there are more LGP-30's installed and working right this minute than any other electronic computing system in its class?

For more information: write Floyd Ritchie, Royal McBee Corporation, Port Chester, New York.

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ROYAL McBEE | GENERAL PRECISION

ELECTRONIC DATA PROCESSING SYSTEMS

CIRCLE 14 ON READER-SERVICE CARD

PORTABLE INSTRUMENT MEASURES OXYGEN AND MOISTURE IN HYDROGEN AND INERT GASES

The Engelhard Portable Atmosphere Analyzer is an ideal instrument for detection and measurement of harmful impurities usually found in gases used in the manufacture of semiconductors and other electronic devices. Analyzes and records atmospheres in furnaces, glove boxes and other critical areas. Oxygen analysis down to less than 1 PPM, moisture analysis down to 1 PPM. Write for literature.

INDUSTRIAL EQUIPMENT DIVISION
GAS EQUIPMENT SECTION
113 ASTOR STREET • NEWARK, N. J.

FOR DETECTION AND MEASUREMENT OF OXYGEN OR HYDROGEN IMPURITIES IN OTHER GASES

Super-sensitive Deoxo Indicator . . . continuously measures oxygen or hydrogen present as impurities in other gases—from 2 to 200 parts per million oxygen and 4 to 400 parts per million hydrogen. Dual range permits measurement up to .25% oxygen or .50% hydrogen.

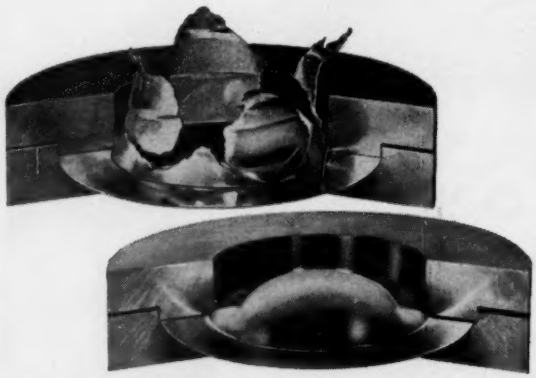
INDUSTRIAL EQUIPMENT DIVISION
GAS EQUIPMENT SECTION
113 ASTOR STREET • NEWARK, N. J.

9 SPECIAL-PURPOSE GRADES OPTICAL FUSED QUARTZ NOW AVAILABLE

Amersil makes 9 special-purpose high quality grades of fused quartz. Each has special characteristics. Included in these 9 grades are some to be used for Ultra-violet transmission and other for Infra-Red. • Used in light sources for radiation, components for optical systems, ultrasonic delay lines and as substitute for rock crystal prisms and lenses in spectographic apparatus, etc. • In addition, lenses and prisms can be supplied in small dimensions.

AMERSIL QUARTZ DIVISION
685 RAMSEY AVENUE • HILLSIDE, N. J.

FOR ATMOSPHERE ANALYZER CIRCLE 15 ON READER-SERVICE CARD
FOR FUSED QUARTZ CIRCLE 16 ON READER-SERVICE CARD



CORROSION-RESISTANT RUPTURE DISCS RELIEVE PRESSURE AUTOMATICALLY

In pressurized apparatus subject to corrosion, dependable precious metal rupture discs provide speediest, safest, most accurate relief from excess pressures. Made of gold, silver or platinum to resist corrosive effects of liquids and gases under conditions that would render many base metal materials useless. Complete line of rupture discs available—guaranteed to burst at ±5% of specified pressure. Economical to use—cost lowered by recovery of precious metal in spent disc. Write for literature.

BAKER PLATINUM DIVISION
113 ASTOR STREET • NEWARK, N. J.

FOR DEOXO INDICATOR CIRCLE 17 ON READER-SERVICE CARD
FOR RUPTURE DISCS CIRCLE 18 ON READER-SERVICE CARD

FOR DETECTION AND MEASUREMENT OF OXYGEN IMPURITIES IN OTHER GASES

In metallurgical and chemical processes requiring an oxygen-free atmosphere, the Minoxo Indicator provides a means of insuring that failure of purification or ingress of atmospheric oxygen through an unsuspected leak does not cause costly spoilage. The Minoxo Indicator . . . measures traces of molecular oxygen in other gases—from 0 to 10 parts per million, and from 0 to 100 PPM. High sensitivity and rapid speed of response enable it to be used for laboratory investigation and production quality control.

INDUSTRIAL EQUIPMENT DIVISION
GAS EQUIPMENT SECTION
113 ASTOR STREET • NEWARK, N. J.

HERMACH-ENGELHARD MULTI-RANGE TRANSFER VOLT-AMMETERS FOR UNMATCHED ACCURACY

Meets exacting calibration requirements for accuracy without use of correction factors over wide range of currents and voltages. Functional design employs null principle . . . provides simple operation. Hermach-Engelhard Transfer Volt-Ammeter achieves 0.05% accuracy through frequency range d-c to 50,000 cps, eliminating complete battery of measuring devices otherwise needed. • Several models available for efficient adaptability to various conditions. Write for details.

INDUSTRIAL EQUIPMENT DIVISION
INSTRUMENTS AND SYSTEMS SECTION
850 PASSAIC AVENUE • E. NEWARK, N. J.

PRECIOUS METAL CONTACTS FOR HIGH-RELIABILITY

Precious metal contacts in pure or alloyed forms of silver, platinum, palladium and gold provide unmatched resistance to atmospheric corrosion, deformation, arc erosion, binding and metal transfer. Baker high-reliability precious metal contacts are supplied as wire, rod, sheet and in a complete line of fabricated forms. Facilities are also available for manufacture to your specifications.

BAKER CONTACT DIVISION
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FOR MINOXO CIRCLE 19 ON READER-SERVICE CARD
FOR PRECIOUS METAL CIRCLE 20 ON READER-SERVICE CARD

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EXECUTIVE OFFICES:
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Please send literature as indicated below, addressed to my attention:

☐ Minoxo Indicator ☐ Precious Metal Contacts

☐ Super-Sensitive Deoxo Indicator ☐ Rupture Discs

☐ Portable Atmosphere Analyzer ☐ Fused Quartz

☐ Hermach-Engelhard Volt-Ammeters

NAME.....

TITLE.....

FIRM.....

STREET.....

CITY.....ZONE.....STATE.....

FOR VOLT-AMMETERS CIRCLE 21 ON READER-SERVICE CARD

ICS TRENDS

The electronics industry, which increased its volume almost five times during the past 13 years, will again double or treble by 1970, says Armour Research Foundation of University of Illinois. The industry volume, estimated at $10 billion in 1960, was expected to climb to above $20 billion in this decade. The electronics industry was recommended as being particularly adapted to profitable operation in Maine, partially because of that state's proximity to the extensive research activities in the Boston vicinity. Nearly one-half the electronics producers are located in Northeast USA.

Japanese exports of electronic products to the United States during 1960 totaled $94.0 million, a 24% increase over the $75.6 million total of 1959, the Electronics Division, Business and Defense Services Administration, U.S. Department of Commerce, reports. Radio receivers accounted for 74% of the total shipments. Other products showing substantial gains were sound recorders and reproducers, radio-phonographs, speakers, receiving tubes, and other electronic components. Exports to the U.S. were equivalent to 48% of total Japanese exports of electronic products to the world in 1960, compared with 56% in 1959.

The volume of total United Kingdom export deliveries of scientific and industrial instruments and apparatus in the third quarter of 1960 was $32 million, 33% higher than third-quarter 1959. Greatest export gain was in the industrial process measuring and control instruments classification, with 25% of total exports, says BDSA, Dept. of Commerce.

Computer census in April DATA PROCESSING magazine says that 4,927 commercial digital computers were in use at the beginning of 1961, made by 20 different companies. To be delivered in 1961-62 are 6,453 digital computers. Of the machines in use, the Federal government has 494 (with 46 special machines bringing its total to 540, and another 100 to be delivered in 1961); local governments have 130; universities 138; with the balance in finance, business and industry

CORRECTION:
Computer census reported from data by John Diebold and Associates in our Feb., 1961 issue was based on Jan., 1960 data. The following is data as of July, 1960: Number of large-scale computers is 607 (up 12% over Jan. 1960) including 175 IBM-705 and -705III and 130 IBM-704. Medium-scale computers delivered—840 (up 24% over Jan. 1960) including 345 IBM-650 with tape or Ramac, and 158 Bendix G-15 with tape. Small-scale computers—2810 (up 16% over Jan. 1, 1960), including 1280 IBM-650 card-type, 775 IBM-305, 425 Royal-McBee LGP-30. Miscellaneous types—6717, including 4800 IBM-604. A Jan. 1961 report issue by JDA reports that 661 transistorized computers have been delivered.

TABLE 1.—*Scientists and engineers, by occupational group, January 1958 and January 1959, and percent change*

Occupational group	Number		Percent change
	January 1958	January 1959	
All groups	730, 500	764, 100	4. 6
Engineers	587, 400	615, 400	4. 8
Chemists	69, 500	71, 500	2. 9
Physicists	13, 400	14, 900	11. 4
Metallurgists	10, 600	11, 400	7. 3
Geologists and geophysicists	15, 400	14, 800	−4. 1
Mathematicians	9, 600	11, 300	16. 9
Medical scientists	6, 700	7, 000	4. 5
Agricultural scientists	5, 000	5, 600	11. 3
Biological scientists	5, 000	5, 500	11. 4
Other scientists	7, 800	6, 600	−14. 7

NOTE.—Totals and percents have been calculated on the basis of unrounded figures and therefore may not correspond exactly with those indicated by the rounded figures shown.

NEW BARTON 273 PNEUMATIC TRANSMITTER MEETS MORE APPLICATION REQUIREMENTS THAN ANY OTHER TRANSMITTER

The Barton 273 offers the widest differential pressure ranges (0-8" w.c. to 0-400 psi), the highest safe working pressures (to 10,000 psi), and the widest variety of housing materials (aluminum, brass, steel, 316 stainless steel). It's compact, weighing up to less than ½ the weight of other units. It has adjustable suppression up to 80% of DP range, and adjustable span. A non-bleed relay minimizes air consumption. It doesn't shift zero on overrange. It's unaffected by normal piping stress. In every respect, the Barton 273 is the most significant advance in pneumatic transmitters in the past decade. There's a lot more you should know about it—for complete data write

BARTON

INSTRUMENT CORPORATION, 580 MONTEREY PASS ROAD, MONTEREY PARK, CALIFORNIA.

CIRCLE 22 ON READER-SERVICE CARD

ICS NEWS

Mexico Forms Instrument Suppliers Association

MEXICO CITY, MEXICO—Instrument men in Mexico have completed the formation of an association of instrument suppliers.

The Asociación Impulsora de Instrumentación Industrial A. C., (c/o Servo Mex, S. A., Oaxaca # 28-601, Mexico 7, D.F.), is headed by *Carlos Delgado*, president, with *Ernesto Weber* as secretary, and has the Mexico offices of most of the major instrument companies as members.

NASA gets Largest Analog Computer

LONG BRANCH, N. J.—The world's largest and most advanced general purpose analog computer, designed and built for the National Aeronautics and Space Administration, is now undergoing final inspection and check-out at Electronic Associates, Inc., West Long Branch, N. J., plant. Developed and built by EAI under a $1,510,000 contract, all units of the computer will be installed at NASA's Langley Field, Va., research center this spring. The computer system will be used for analytical computation in a vast electronics calculation program for simulating future satellite and space vehicle programs. It occupies more than 1,800 square feet of floor space and comprises five separate PACE 231R computer consoles, which will be used separately or in slaved groups with a sixth unit already installed at Langley Field.

NBS Selects Martin to Calibrate Standard Cells

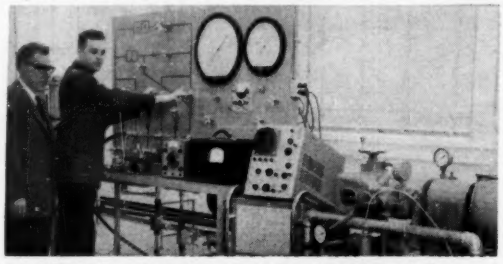
BALTIMORE, MD.—The Martin Company has been selected by the National Bureau of Standards as one of a number of companies in the nation to calibrate unsaturated or "working" standard cells for private industry and research laboratories. (The Martin Company joined with the Bureau last September in support of this country's first Institute of Measurement Science, at George Washington University.) Martin was selected for this because it has a number of saturated standard cells, required to calibrate the unsaturated working cells. The saturated cell's accuracy can be calibrated to within 0.001%; the unsaturated type has an accuracy of 0.01%.

AMERICAN METER CO's common stock recently was traded on the floor of the New York Stock Exchange for the first time in the company's 125-year history.

AMERICAN METER COMPANY and Roots-Connersville Blower Division, Dresser Industries, announce that American will sell and service the complete line of Roots positive-displacement rotary meters (designated as American Rotary Meters), while Roots-Connersville will continue to sell Rootsmeters, with accessories made by American.

Automatic Control Center at Purdue University

LAFAYETTE, IND.—An Automatic Control Center has been established at the School of Mechanical Engineering at Purdue, staffed by over twenty professors, research assistants, post-doctoral associates, and other personnel. The research assistants are working toward masters and Ph.D. degrees in the School of Mechanical Engineering. The center has a well-equipped, air-conditioned laboratory where frequency response runs are being made on hydraulic lines under ambient conditions.



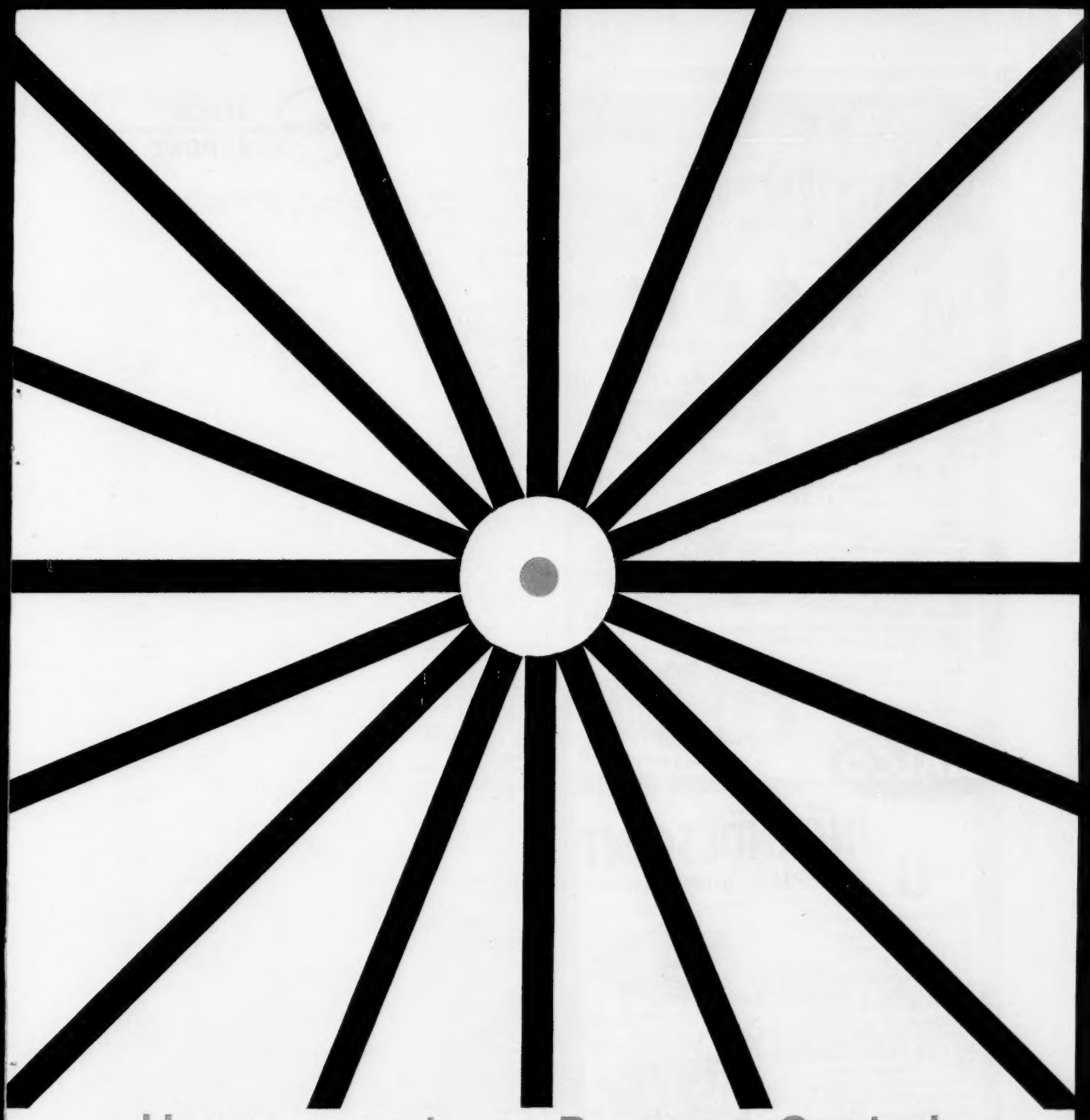
PROFESSOR RUFUS OLDENBURGER (left) and **MR. R. E. GOODSON** (right), graduate student, testing hydraulic equipment in laboratory.

The major financial support for the center has come from NASA. Substantial help has been received from Purdue University, the National Science Foundation, the Office of Naval Research, FIER, and other sources. Research is currently going on in the areas of optimum nonlinear control, dynamic response of hydraulic systems, stabilization of control systems, algebraic approaches to control system design, adaptive control, and multiple control. A Royal McBee LPG-30, Datatron and a Reming-

MR. R. E. GOODSON (left), graduate student, and **PROFESSOR RUFUS OLDENBURGER** (right) discussing computer problem in laboratory.

ton Rand 880 are digital computers available to the staff of the center. The ME Department has ordered a Royal McBee RPC-4000 digital computer which should be ready for staff use by June 1, 1961. There are currently two full professors on the staff, Dr. E. H. Gamble, and Dr. R. Oldenburger (director of the center).

Four courses are being offered by the staff—(1) regulators and servomechanism, (2) statistical approaches to automatic control, (3) nonlinear automatic control, and (4) linear control theory. These are graduate courses, some of which are open to seniors. The Department of Mechanical Engineering is establishing an automatic-control course for all ME students at Purdue. Outstanding automatic control experts are brought to Purdue to give open lectures on automatic-control.



Hagan reports on Pressure Control

Dealing with full scale pressures ranging from 6,000 psi to .2″ water is routine with Hagan. Maintaining the desired conditions within 0.1% of full scale is equally routine. Hagan has instrumentation and final control elements that can handle compressors, exhausters and valves from tiny laboratory equipment to the 10-ton giants used in wind tunnels. Packaged to handle corrosive atmospheres and Division One area requirements, they are extremely easy to maintain and troubleshoot.

At one installation where valve position may change as much as 30°, a Hagan pressure control system is holding pressure within ±0.5% of full scale . . . despite the fact that air flow changes from 0 to 600 lb/sec in less than 5 seconds. This system is made up of standard Hagan components, demonstrating the range and accuracy of the equipment.

Measuring and regulating all the variables that enter into process control is a part of Hagan's forty years of experience in the design and manufacture of instrumentation and control elements. Designed for a high degree of reliability and accuracy, Hagan components are also versatile in application; a very desirable characteristic in relation to inventory and stocking problems. For more information on the complete Hagan line of electronic, pneumatic and hydraulic controls, write or telephone HAGAN CHEMICALS & CONTROLS, INC., Hagan Center, Pittsburgh 30, Pa. Phone WAlnut 2-3737.

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HIGH BRIGHTNESS and REGULAR TYPES

DIALCO's Sub-Miniatures use tiny T-2 Neon Glow Lamps: *NE-2J (High Brightness)* at 105-125 V., A.C.; or *NE-2D* (regular) at 105-125 V., A.C. or D.C.

NEW Series mounts from *FRONT* of panel in 15/32" clearance hole (supplements 17/32" Series). Also—units for mounting from *BACK* of panel in 15/32" clearance hole. Unique lenses in 5 colors; give all-angle visibility. Units are fully insulated; meet applicable Mil. Specs.

Ask for Brochures L-159C and L-160B.

(Illust. approx. actual size)

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No. 145-5036-991

(Back mtg., 15/32")

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T-1¾

2-TERMINAL and 1-TERMINAL TYPES

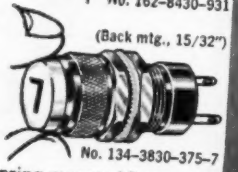
Designed for use with T-1¾ midget flanged incandescent lamps—1.3 V. to 28 V... *NEW* Series mounts from *FRONT* of panel in 15/32" clearance hole—(supplements 17/32" Series). Also—units for mounting from *BACK* of panel in 15/32" clearance hole. Unique lenses in 7 colors. Units are fully insulated; meet applicable Mil. Specs.

Ask for Brochures L-156D thru L-159C.

(Front mtg., 15/32")

No. 162-8430-931

(Back mtg., 15/32")



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Spring-mounted Lens-with-Message is *rotatable*.

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For use on *grounded circuits*. Mount in 13/32" or 15/32" clearance hole. Binding screw or soldering terminal.

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CIRCLE 24 ON READER-SERVICE CARD

ICS STOCK REPORT

Further information may be obtained from the Research Department, Bache & Co., 36 Wall Street, New York 5, N. Y.

NEW YORK STOCK EXCHANGE

PRICE RANGE FOR 1961 THRU APRIL 14, 1961

	High	Low	Price As Of 4/14/61
ACF Industries	58 1/2	38	54 1/8
Aeroquip Corp	35 3/4	22 1/4	34
Allis Chalmers	27 7/8	23 3/8	25 3/8
American Chain & Cable	50 1/4	42 7/8	50 1/4
Amer. Mach. & Foundry	125 1/4	85 1/4	124 1/2
Amer. Mach. & Metals	44 3/4	34 1/8	40 3/4
American Meter	53 3/4	43	51 1/4
American Optical	68 3/4	54	67 3/4
American Tel. & Tel.	130	103 1/8	128 3/4
Ampex Corp.	26 1/2	20 1/4	26 1/2
Aro Equipment	34 7/8	20 1/8	34 1/8
Bausch & Lomb Optical	46 5/8	39 3/4	41 5/8
Beckman Instruments	141	87	129 3/4
Bell & Howell	63 1/4	48 3/4	56 5/8
Bendix Aviation	72	61 3/4	64 7/8
Boeing Airplane	47 5/8	35 1/2	43 1/8
Bullard	17 3/4	11 1/4	16 1/8
Bulova Watch	18 3/4	15 7/8	18 3/4
Burroughs	38 1/4	27 1/2	35 3/8
Carborundum	59	44 1/4	53 1/2
Cinn. Milling Machine	49 1/4	37 1/2	45 1/2
Clevite	65	47 3/4	64
Columbia Broadcasting Sys.	40 1/2	35 3/8	39 1/2
Consol. Electronics	46 1/2	36 1/8	41 1/4
Corning Glass	194 3/4	167	183 1/4
Curtiss Wright	22	15 5/8	20 1/2
Cutler-Hammer	74	62 3/8	69
Daystrom	34 3/4	25 3/8	26 1/4
Douglas Aircraft	38 1/2	28	32 1/8
Eastman Kodak	119 3/4	104 1/4	116
Eaton Mfg.	38	30 3/8	35 1/2
Electric Auto-Lite	67 3/4	44 5/8	63
Elgin Watch	15 1/4	11 3/4	14 3/8
Emerson Electric	81 3/4	50	77 3/4
Engelhard Industries	22 7/8	18 1/2	22
Food Mach. & Chem.	76 1/2	59 1/8	74 1/2
Garrett	56 3/8	48	50 3/4
General Controls	22 1/2	17 3/4	18 5/8
General Dynamics	45 1/2	38 5/8	38 3/4
General Electric	74	61 1/8	63 3/4
General Instruments	53 7/8	37 5/8	52 1/4
General Mills	37	31 3/8	32 7/8
Gen. Precision Equip.	75 5/8	54 1/2	68 1/4
Gen. Railway Signal	54 1/2	29	54 1/2
Gen. Tel. & Elect.	32 1/2	26 1/2	31 1/8
General Time	20 3/8	14 1/4	17 3/8
General Tire & Rubber	68 1/2	53 3/4	64 7/8
Hewlett-Packard	53	36 3/4	47 3/4
International Bus. Mach.	733	580	716
International Resistance	40 1/4	26	40 1/4
Internat'l. Tel. & Tel.	60 7/8	44 3/4	60 1/8
I-T-E Circuit Breaker	24 5/8	19 3/4	20 1/2
Lear Inc.	25	16	22 7/8
Litton Industries	130 3/4	87 1/8	128
Lockheed Aircraft	45 5/8	26 1/2	40 3/4
Magnovox	84 1/2	46	82 1/8
Mallory	51 1/2	36 5/8	48 1/4
Manning, Maxwell & Moore	26 1/2	21 7/8	25
Minneapolis-Honeywell	170 3/4	140	158 3/4
Minnesota Mining & Mfg.	84 1/2	70 1/8	83 3/4
Motorola	92	75 1/8	88 3/4
National Acme	59 1/2	47	53 1/4
National Cash Register	90 1/2	61 7/8	90 1/2
Neptune Meter	29 1/2	22 7/8	24 1/2
North American Aviation	53 5/8	41 5/8	47 3/8
Northrop Aircraft	63 1/2	41 1/2	63 1/2
Otis Elevator	79	56 1/2	75 1/4
Philco Corp.	24 1/4	17 3/4	23 1/4
Radio Corp. of Amer.	62 1/2	49 1/2	61 1/4
Raytheon Mfg.	42 7/8	35 1/4	38 1/2
Reliance Electric	67	47 1/2	59 1/2
Rheem Mfg.	18 1/4	13 1/2	16 1/8
Robertshaw Fulton	41 1/4	32 7/8	37 7/8
Royal McBee	17 1/4	13 1/4	16 1/4
Sangamo Electric	16 5/8	14 3/8	15 3/8
Siegler Corp.	34	27	32
Sperry Rand	29 1/4	20 1/2	29
Square D	39 1/8	29 5/8	36 5/8
Standard Kollsman	47 1/4	25 1/8	47 1/4
Starrett (L.S.)	22	17 3/4	19 3/4
Stewart-Warner	28 5/8	24 3/4	27 3/4
Telautograph	16 1/4	12 5/8	15 3/4
Texas Instruments	204	165 3/4	198 3/4
Thompson-Ramo-Wooldridge	82 3/8	67 3/4	73
Tung-Sol Electric	31 5/8	25 3/8	29 1/2
Underwood Corp.	59 1/2	42 1/2	57 3/4
Union Carbide Corp.	135	116	133
United Shoe Machinery	76 1/4	54 5/8	69 3/4
Varian Associates	67 1/8	46 5/8	67 1/8
Wallace & Tiernan (new) (a)	41 1/2	26 1/2	38 1/2
Western Union	55	39 3/4	48 1/8
Westinghouse Air Brake	27 7/8	22	27 1/2
Westinghouse Electric	50	40 5/8	42 3/4
Worthington Corp.	59 7/8	49	57 7/8

These prices and price ranges are given as printed in the Wall Street Journal.

AMERICAN STOCK EXCHANGE

PRICE RANGE 1961 THRU APRIL 14, 1961

	High	Low	Price As Of 4/14/61
Barry Wright	29 3/4	15	27 1/2
Belock Instruments	19 5/8	14 5/8	17
Benrus Watch	7 5/8	6	7 1/8
Breeze Corp.	6 3/4	4 1/8	5 3/4
Burnell & Co.	13 7/8	6 1/2	13 7/8
Clark Controller	19 5/8	16 1/2	19 1/2
Clarostat Mfg.	20	12	17 1/2

STOCK REPORT

(*Continued from page 774*)

Clary Corp.	15 1/2	8 5/8	13 7/8
Cubic Corp.	91 1/2	51 1/2	90
Dynamics Corp. of Amer.	14 3/8	7 5/8	14 3/8
El-Tronics	9 3/4	5	8 1/8
Electronics Corp. of Amer.	13 3/4	9	11 3/4
Fairchild Camera & Instruments	184 1/4	130	184 1/4
Fischer & Porter Co.	29 1/2	16	27 1/2
Giannini Controls	71 1/2	52	67
Globe Union	31 1/2	23 1/2	30 3/4
Hazeltine Corp.	44 1/2	25 1/2	44
Loral-Electronics (new) (a)	46 1/4	31 5/8	42
National Research	31 7/8	17 5/8	28 7/8
New Haven Clock	2 1/4	1 1/8	2 1/4
Nuclear Corp. of Amer.	6 3/8	3 7/8	5 5/8
Philips Electronics, Inc.	38 1/2	32 1/4	34 3/8
Pneumatic Scale	50	39 1/2	42
Polarad Electronics	27 3/4	18 3/4	25 5/8
Servo Corp. of Amer.	19	11 1/4	16 1/4
Servomechanisms	11	7 3/4	9 7/8
Statham Instruments Inc.	35 3/8	26	29 1/4
Textron Electronics	12 1/2	9 3/8	10
Victoreen Instrument Co.	18	13 1/8	15 1/2
Waltham Prec. Instr. Co.	3 1/8	1 3/4	3

These Prices and price ranges are given as printed in the Wall Street Journal.

OVER THE COUNTER

	Quotation As Of April 14, 1961 Bid	Asked
Aerovox Corp.	9	10 1/4
Argus Corp.	38 3/4	39 1/2
Black Sivalls & Bryson Inc.	15 1/8	16 3/8
Computer Systems	29 1/2	31
Eitel Mc Cullough	18	18 1/2
Electro Instruments	27	29
Electronics Associates	37 1/2	38 1/2
Erie Resistor Corporation	17 1/8	18 1/2
Fisher Governor Co.	24 3/4	25 1/4
Foxboro Company (new)	85	88
Hagan Chemicals & Controls	57 1/2	62 1/2
Huigo Electronic Corp.	26	27 1/2
Industro Transitor	5 3/4	6 1/2
Liquidometer Corp.	17	18 1/2
W. L. Maxson	30 3/4	31 1/2
Penn Controls	24 1/2	26
Speer Carbon, Inc.	22 1/4	24 1/8
Sprague Electric	65	68 1/4
Taylor Instruments (new)	45 1/2	47
Telechrome Mfg. Corp.	16 3/8	16 7/8
Telecomputing Corp.	6 7/8	7 1/2
Vitro Corp. of Amer.	22 7/8	24 1/2
Wallson Associates Inc.	6	6 1/2

PANORAMIC PERSPECTIVE

113° EXTREME WIDE-ANGLE COVERAGE

This unbelievably clear and sharp photograph of over 120,000 sq. miles of the earth's surface was shot from a Thor intermediate ballistic missile at an altitude of 300 miles, with a KINOPTIK 5.7 mm f/1.8 APOCHROMAT. Free from distortion and with an unsurpassed degree of clarity, definition and contrast, this extraordinary picture exemplifies the outstanding wide-angle coverage (113°) of this unique lens.

KINOPTIK 5.7mm f/1.8 APOCHROMAT

KINOPTIK APOCHROMATS, the only complete series of more than 20 handpicked, high-speed and perfectly color-matched (T-stopped) lenses for 16mm and 35mm movie or TV cameras:

1.9mm f/1.9*	40mm f/2
5.7mm f/1.8*	40mm f/2.8
9.8mm f/1.9	50mm f/1.3
12.5mmf/2.5*	50mm f/2
18mm f/2	50mm f/2.8
20mm f/1.9*	75mm f/2
25mm f/2	100mm f/2
28mm f/2	150mm f/2.5
32mm f/1.9	210mm f/2.8
32mm f/2.8	300mm f/3.5
35mm f/2	500mm f/5.6

* for 16mm only

Available in C- and Barrel-mount, for Arriflex, Cine-Special, Eyemo, etc.

ALSO: Stigmar lenses for Microfilm—65mm, 68mm and 75mm f/10. Optical Amplifiers for 16mm and 35mm Cameras f/1.3. Collimator-Reflex with 2 interchangeable 275mm and 485mm lenses.

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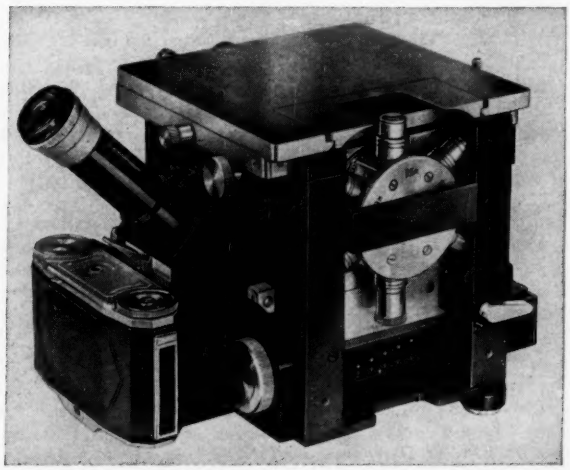

Write for detailed literature and specifications on this industrial microscope.

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WEST GERMANY

INTERFERENCE MICROSCOPE

For accurately measuring minute depths of roughness of super-finished surfaces, thickness of coatings, changes of surface structures due to wear, impact, stress, strain, corrosion, as well as for the studying of polished and etched metallurgical specimens.

Magnifications of 80x, 200x and 480x. Built-in Thallium and white light illuminators. Photography on 35mm film (1 x 1½ in.)

CARL ZEISS, INC.

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COMPLETE SERVICE FACILITIES

CIRCLE 26 ON READER-SERVICE CARD

Foxboro to Install RCA Computer in Power Station

FOXBORO, MASS.—The Foxboro Company has received a contract by New England Electric for advanced automation equipment to be installed at the new $80,000,000 Brayton Point power station in Somerset, Mass. The first of two large generating units is scheduled for completion in the Spring of 1963. Over a quarter of a million dollars will be invested in a digital computer to assure the utmost safety, economy and reliability of two new 250,000-kw generating units.

Foxboro will have prime responsibility for computer design and associated instrumentation. The computer (an RCA 110) will have four main functions: accept and selectively display data from more than 1100 critical points in the efficiency and performance of power generating equipment; record measurement trends; and monitor the sequential steps in plant operation.

BAILEY METER CO has sold a solid-state Bailey 750 Information System to Consumers Power Company of Jackson, Michigan. Designed for 300 inputs, the system will initially handle 150. A magnetic drum is used to store the system's single program.

Bus Line Telecommunication

ELGIN, ILL.—A new telecommunications system engineered and built by the Kleinschmidt Div. of Smith-Corona Marchant Inc., will soon span a board section of the United States with the system. Greyhound Corp. is the first transportation company to employ the new telecommunication system in 46 field stations in the Midwest, with master control centers located in Kansas City, Mo., and Dallas, Tex.

Heart of the new system is the Teleswitcher "B," which automatically monitors and controls all communications between the stations. There are two Teleswitchers in the system, located at the master control stations. Equipment at the master stations also includes a typing reperforator, tape transmitter, and two page printers. In each of the 46 field stations, equipment consists of a page printer, typing reperforator, and tape transmitter.

The teleswitcher's line scanner automatically questioning each station according to a pre-determined program, as to whether it has any data or messages to transmit, then automatically routes the message to the proper station or stations. A code prevents wrong routing, and built-in safety features insure proper transmission. Emcor cabinets (made by Ingersoll Products Div., Borg-Warner, 630 Congdon Ave., Elgin, Ill.) were used.

KEARFOTT DIVISION, General Precision, Inc., has under development a pneumatic digital computer claimed to be able to do everything an electronic or mechanical computer can do but which is "smaller, cheaper, more reliable, and easier to service and test." Another Kearfott development is a **Hall-effect resolver,** with a complete line of solid-state synchros and resolvers to follow.

Pilot Plant and Process Automation

LOS ANGELES.—The Third Symposium on Pilot Plant and Process Automation was held April 5-6 at the Ambassador Hotel in Los Angeles. Attendance at this invitational meeting was limited to 120. The symposium was sponsored by Consolidated Electrodynamics/Consolidated Systems; Daystrom, Control Systems Division; TRW Computers Company; and Robertshaw-Fulton Controls Company. The program, arranged and controlled by a users' committee, was divided into four sessions: Education for automation, ways of obtaining data, how to interpret data, and control and optimization through use of the data. The last session included case histories of several existing process control installations.

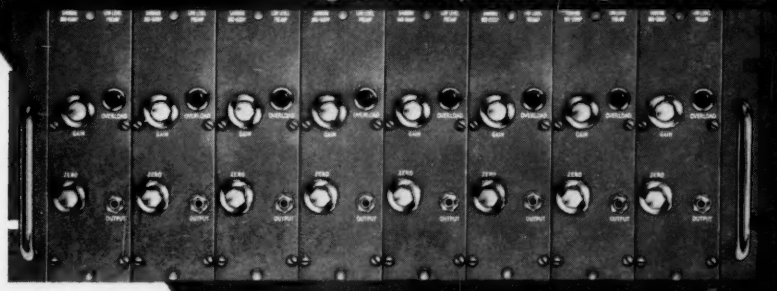
One of the speakers on the final panel estimated that there are 101 on-line process control computer installations operating today in this country. Both analog and digital installations are included in this estimate.

MINNEAPOLIS-HONEYWELL has furnished Philadelphia Electric Co. with a digital computer control system which will automatically assign the total requirements to the generating units on the most economical basis, as well as provide cost data on power interchanged with members of the Pennsylvania-New Jersey-Maryland Interconnection.

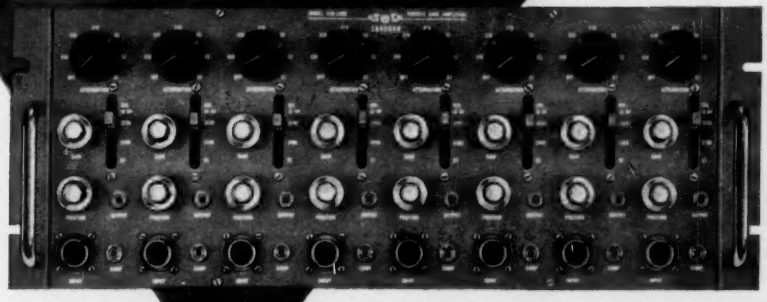
ELECTRONICS ASSOCIATES will again hold courses in Analog Computer Applications, scheduled for June 5-16 at the Los Angeles Computation Center, and October 23-November 3 at the Princeton Computation Center. A similar course on Analog Computation in the Chemical and Petroleum Industries will be held August 14-25 at Princeton Computation Center. Tuition fee is $400.00 for either course. For information contact the Director of Training and Education, Princeton Computation Center, Box 582, Princeton, N. J.; and Director, Los Angeles Computation Center, 1500 East Imperial Highway, El Segundo, Calif., respectively.

FOXBORO COMPANY participated (through its vice president in charge of marketing, Charles Schwarzler) in the seventh United States Trade Mission held in Japan until May 9. Sponsored by U. S. Department of Commerce, the Trade Mission will provide Japanese industry with information on the latest U. S. technological developments, and furnish information on U. S. sources of machinery and equipment supply.

Model 860-1500P — handles low level DC data signals in the presence of high common mode



Model 658-3400 — drives high frequency optical galvanometers to 5 KC



COMPACT 7" HIGH 8-CHANNEL UNITS ARE COMPLETELY TRANSISTORIZED, HAVE FLOATING INPUT ISOLATED FROM OUTPUT

Sanborn precision amplifiers

▼ Data Preamplifier — Model 860-1500P

Designed for precise, economical amplification of signals with source impedance of zero to 10,000 ohms, such as thermocouples, strain gage bridges, etc. in presence of severe ground loop noise, and for driving digital voltmeters, scopes, tape recorders and similar devices. Each plug-in unit is only 2" x 7" x 14½" deep; 64 channels with blower require only 60" of rack-panel space. Separate 868-500 Power Supply required for every 8 preamplifiers. Power consumption 2.5 watts per channel.

Noise	3 uv peak-to-peak
Gain	100 (10 mv in gives 1 v out) (Model 860-1500PA with gain of 1000 also available)
Output	± 1 v across 300 ohms, DC-70 cps; ± 1.5 v to 40 cps. Output impedance 100 ohms. (10 v across 10K available on special order.)
Linearity	± 0.1% of full scale output (2 v)
Common Mode Performance	120 db rejection at 60 cps, 160 db at DC, with 5000 ohms unbalance in source. Inphase tolerance 220VAC.
Input Impedance	Greater than 200,000 ohms
Gain Stability	± 0.1% for 24 hours
Drift	± 2 uv referred to input
Rise Time	to 99.9% less than 25 ms

▼ Optical Galvanometer Amplifier — Model 658-3400

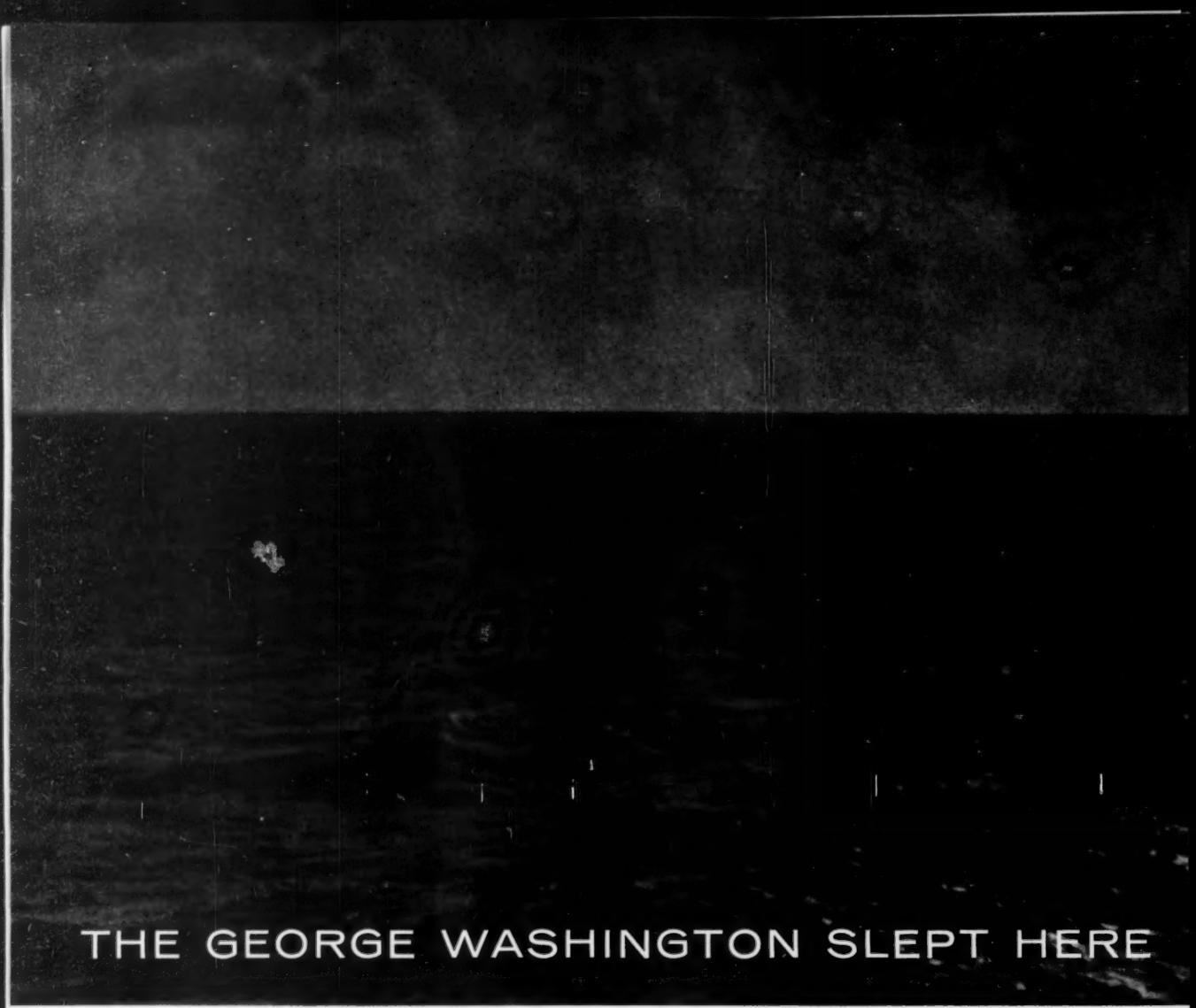
Eight channels of amplification and common power supply. Each channel provides for sensitivity, compensation, damping and current limiting. Inputs floating and guarded, impedance 100,000 ohms on all ranges. All amplifier elements except output transistors are plug-in assemblies.

Sensitivity	± 10 mv input gives ± 400 ma output into 20 ohm load (max.). Eleven attenuator steps to X2000 in 1-2-5 ratio, smooth gain control.
Common Mode Performance	± 500 volts, max; rejection 140 db min at DC.
Gain Stability	Better than 1% to 50°C and for line voltage variation from 103-127 volts.
Frequency Response	0 to 5 KC within 3 db; can accomodate wide range of galvanometers.
Output	Output networks available for wide range of galvanometers.
Power Consumption	125 watts for 8 channels.

Your Sanborn Sales-Engineering Representative (offices throughout the U. S., Canada and overseas) will provide detailed information and application assistance. Call him or write plant in Waltham, Mass.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

CIRCLE 27 ON READER-SERVICE CARD



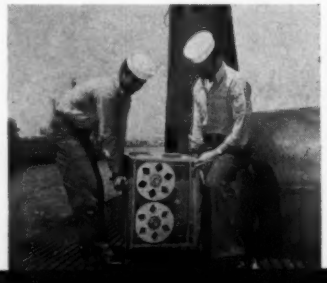
THE GEORGE WASHINGTON SLEPT HERE

BUT NOT FOR LONG. Somewhere off the Atlantic coast the big nuclear-powered *George Washington* catnapped between vibration tests made during submarine launchings of the first two Polaris missiles.

The firings were made part of "first-of-a-class" tests conducted by the Navy's David Taylor Model Basin during a 2-month period last summer. Vibration characteristics of the sub's hull, fairwater, missile and propulsion systems were recorded.

Mounted in the torpedo room of the *George Washington* were two oscillographs and a 14-channel magnetic tape recorder for recording the output from 38 velocity transducers—all products of Consolidated Electrodynamics Corporation. Output of the transducers, recorded on the tape recorder and oscillographs, was electrically integrated to produce signals proportional to displacement.

CAPABLE...RUGGED—The Electric Boat Division of General Dynamics Corporation built the *George Washington*. Electric Boat was responsible for the design and construction phase, and tested the sub at dockside and at sea in builder's trials that included tests of the torpedo system, missile firing, maneuvering and vibration characteristics, and the electrical and hydraulic systems.



At Electric Boat, CEC equipment has proved its capability—and ruggedness—in the highly important area of design measurement. The two oscillographs with DATARITE Magazines have been moved in and out of a sub as many as 25 times to help solve problems of malfunctioning systems. They've operated at 25 to 30-degree pitch and roll angles at sea and at 70-degree angles in the laboratory.

THE SEARCH FOR A TRUE SUBMARINE—CEC's role in the development of submarines as a stronger arm in the nation's defense began with the habitability cruise of the *Nautilus*, the first U.S. nuclear-powered sub. On board was a "specialist" in atmospheric hydrocarbons: a CEC mass spectrometer. It had been modified for use by the U.S. Naval Research Laboratory on the *Nautilus* to detect and measure contaminants that affect the underwater capability of submarines—contaminants from paints, floor wax, and cleaning solvents, from the breakdown of fuel oils and lubricants, even from cooking.

The mass spectrometer was converted by CEC at the Naval Research Laboratory for continuous analysis of gaseous and liquid samples in a mass range broadened to include masses from 2 to 150.

The instrument faced measurement problems never encountered in a labora-

tory: the roll of the ship, ambient temperatures as low as 50°F., humidities ranging as high as 80 to 90%. Even routine tests became tedious, but the mass spectrometer continued to collect and analyze gas vapor trace contaminants—contaminants that might make the atmosphere aboard nuclear subs unwholesome for crew members to live and work in during long periods of submergence.

HISTORY IN HEADLINES—When the habitability cruise ended, the Navy had many facts it needed and immediately launched a similar program for each of its nuclear subs. The use of cleaning solvents was rigidly controlled. Later, all painting was terminated several weeks before a long submergence period. Finally, all materials containing undesirable contaminants that could not be eliminated aboard ship were simply left ashore.

What has happened since in the Navy's search for a true submarine is headline history. In the fall of 1957, the *Nautilus* was submerged for 5½ days under the Arctic ice pack. In the months that followed, her sister subs set 16-day and 30-day endurance records . . . then a 2-month record . . . then a circumnavigation of the world that lasted 84 days and 41,519 miles.

CEC's applications of mass spectrometry and data recording to underseas problems are perhaps unprecedented. Mass spectrometry and data recording continue to have countless applications in other vital military and defense programs, in research laboratories and throughout industry. There are endless uses for CEC mass spectrometers, oscillographs, tape recorders and transducers. The widespread use of these instruments tells only part of the company's product story.

As one of the world's principal suppliers of precision electronic instrumentation, Consolidated Electrodynamics continues to develop the techniques and electronic tools that give man the ability to measure, and in part control, the dynamic and expanding boundaries of his physical environment.

Since 1937, through research and advances in technology, CEC has helped speed U.S. development of aircraft, missiles, nuclear reactors, and automatic petrochemical plants. With the dawn of an era of automation, CEC's capabilities in instrumentation are available to all men of science and industry. It is an era in which man will be limited only by his imagination.

CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

DATA RECORDERS DIVISION • DATALAB DIVISION • TRANSDUCER DIVISION • ANALYTICAL & CONTROL DIVISION • CONSOLIDATED SYSTEMS CORP. • CONSOLIDATED VACUUM CORP.

A SUBSIDIARY OF **Bell & Howell** • *FINER PRODUCTS THROUGH IMAGINATION*

CIRCLE 28 ON READER-SERVICE CARD

CRESCENT ARMORED MULTITUBE

for INSTRUMENTS & CONTROLS

Individually Numbered Tubes of Copper or Aluminum permit positive identification

Bends Without Distortion of the Tubes Because They Are Cabled Together

INDIVIDUALLY NUMBERED TUBES—Numbers appear at 2" intervals throughout the length, thus permitting positive identification of every tube anywhere along the length, as well as at each end. This is a real time-saving feature as the installers can connect both ends without the necessity for tracing through each tube.

The tubes are thoroughly protected from injury during and after installation by a flexible interlocked galvanized steel armor, TYPE CA, or corrosion resistant polyvinyl chloride thermoplastic sheath, TYPE CT, or combinations of both to meet any corrosive environment.

CRESCENT MULTITUBE is available with 2 to 37 copper tubes, 1/4" O.D., in continuous lengths up to 1000 feet. Also furnished in 1 to 12 tubes in size 3/8" O.D. tubing, or 1 to 4 tubes in size 1/2" O.D.

Substantial savings can be made in installed cost on moderate to long runs with better protected installation of instrument tubing. This product is licensed under U. S. Patent 2,578,280.

Write For Bulletin—No. 960-A

CRESCENT INSULATED WIRE & CABLE CO., INC.

TRENTON 5, NEW JERSEY

CIRCLE 29 ON READER-SERVICE CARD

HOKE Flow Sheet 5

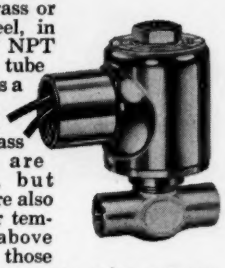
HOKE REPORTS ON FLUID CONTROL

WE'VE TOSSED A NEW BALL INTO AN OLD GAME

A VALVE NAMED "DESIRE"

With apologies to Tennessee Williams, we really have produced a Solenoid Valve line based on *your* desires. We surveyed all the solenoid valve users we could find to determine what *you* wanted. The result is Hoke's "User Designed" Series 90 and 95, two-way and three-way, direct-acting solenoid valve line.

Thanks to you, we have much to brag about. Here's what we have been saying about these new valves: lightest weight – smallest size – no-hum operation – lowest temperature rise – lowest power consumption – stainless steel plunger – silver AC shading coils – easiest installation – packless construction – 360° rotatable housing – operates in any position.



We make them of forged brass or stainless steel, in ⅛" and ¼" NPT size or JIC tube ends. There's a variety of AC and DC voltages. Class "A" coils are standard, but Class "H" are also available for temperatures above 212°F. For those with high insurance rates, we can supply explosion proof coil housings.

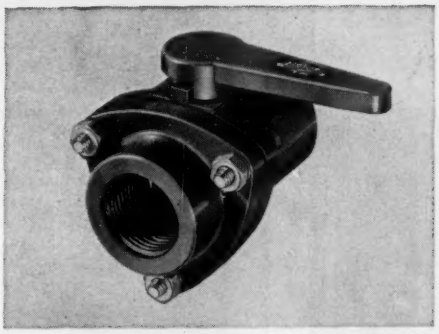
Now that we've bragged a bit, we must also apologize for our premature enthusiasm. We were so excited about this product that we stirred up a hornet's nest of interest before we were ready to deliver in quantity. Shipments were slow at the start, but now we can have any reasonable quantity of these "desirable" solenoid valves "on-stream" in your plant when you want them.

There's only one way to get conclusive performance proof – buy a valve. Ask for Bulletin SV-4-61.

A STEADY FLOW OF FACTS!

Further flow features, and interesting technical topics are carefully covered in Hoke's technical publication, the FLOW SHEET. It's free, but worth millions! To get the full benefit of our engineering and editorial efforts six times a year, mark your "X" in the proper box.

The technique of molding polyvinyl chloride into ball valve parts is old hat. Even the unplasticized compounds of type I PVC have been kicked around for a while (with minor successes). But until now, no one has booted the ball for a goal.



Perseverance, determination, and the pursuit of economic reward have prompted us to offer a line of ball valves molded of the toughest grade of type I, unplasticized PVC. There are no foreign agents to contribute to a corrosive demise, even in most caustic services. It even meets the proposed new ASTM specification and has a tensile strength of 8500 psi. Those who have had PVC piping problems will profit from the new molding process that gives these Hokes dimensional stability and very high impact strength. Sensitive systems, human and otherwise, are safe from contamination – they're absolutely non-toxic. We've set 140°F. as the operating temperature limit, but occasional excursions to 160°F. won't do any harm.

All standard models are supplied with a concentric hole drilled thru the ball. They can be heat welded, or solvent bonded right in the line. Piping hook-up is even simplified by their coupling-like assembly. Your assistant can fit each half of the valve to a pipe end, then reassemble the valve without having to turn the pipe. Pressures to 125 psi are duck soup for these valves.

A maintenance man's delight, they can be cleaned and have their seats changed without leaving the pipe. Their light weight makes them ideal for use on long, unsupported spans of pipe.

Size-wise, we're offering them in ½, ¾, 1, 1½, 2, and 3 inch sizes, all NPT female connections.

You will command the eternal admiration of your colleagues when you install these valves. Be the first to show your rightful status by ordering a shiny new Hoke polyvinyl chloride ball valve. If pride of ownership hasn't motivated you at this point, the mere fact that you are behind the scientific times should move you to find out more.

It isn't necessary to tell us why you want the additional information. Just check the coupon below. We'll forward the facts in a plain, brown envelope.

'61 PRODUCT PARADE

You'd be surprised at some of the screwball ways our valves have been used (to decided advantage, of course). Hoke distributors are armed to their maxillary third molars with this method madness and will redesign your systems (incorporating solenoid valves and PVC ball valves) at the drop of a postcard. Check the PRODUCT PARADE box.

Hoke's Performance Guarantee – *Every Valve Leak-Tested!*

HOKE, INCORPORATED
31 Piermont Road, Cresskill, N. J.

Send me complete information on the Hoke products checked below:

- ☐ PVC Ball Valves
- ☐ Solenoid Valves
- ☐ Product Parade
- ☐ Flow Sheet
- ☐ Complete Catalog GC960

NAME_____ TITLE_____

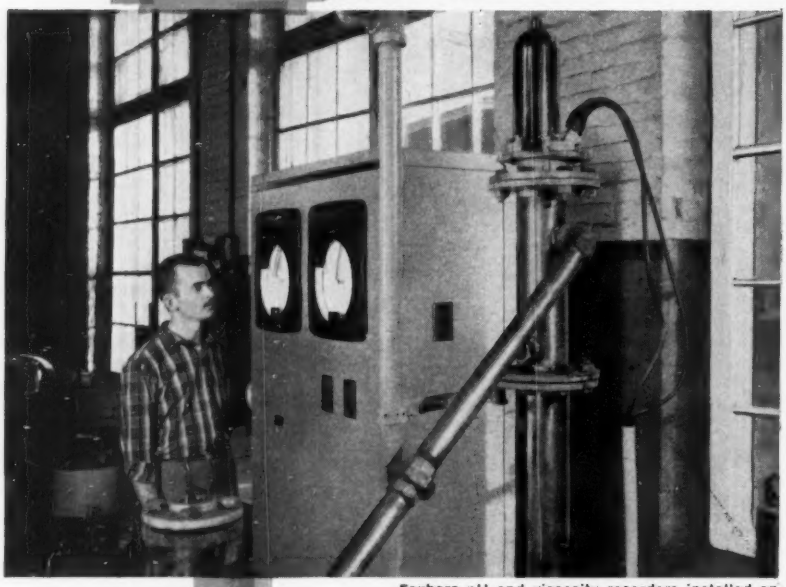
COMPANY_____

ADDRESS_____

CITY_____ STATE_____

SEE OUR CATALOG IN SWEETS PRODUCT DESIGN FILE

CIRCLE 30 ON READER-SERVICE CARD

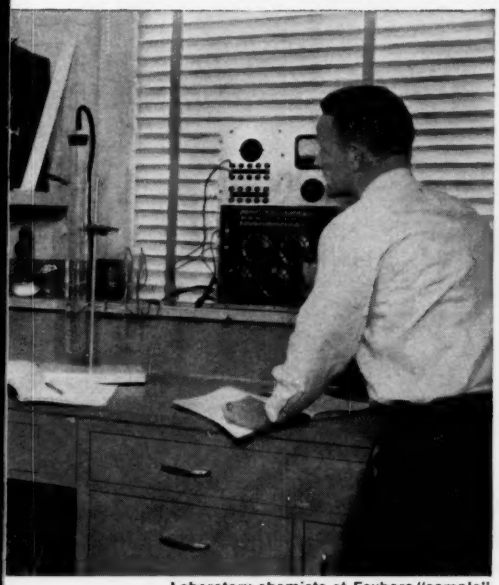


Foxboro pH and viscosity recorders installed on process control panel in a large chemical plant.

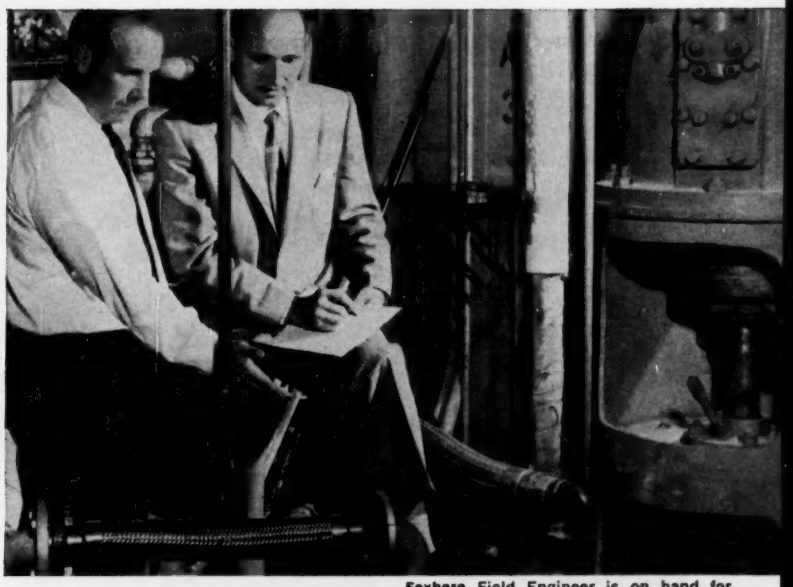
from Foxboro...

the analyzers...the electro-chemical

to help solve your



Laboratory chemists at Foxboro "sample" customer's process fluids to determine dielectric constant and conductivity.



Foxboro Field Engineer is on hand for his customer's all-important start-up day.

know-how...the engineering service process analysis problem!

pH, conductivity, amperometry, dielectric constant, oxidation-reduction potential . . . no matter what analytical measurement characterizes your process, chances are Foxboro can make it for you.

Foxboro's wide range of instrumentation covers the entire control loop. Measuring elements, transmitters, recorders, controllers, alarms — all installed as an integrated system. And all under the single responsibility of The Foxboro Company.

What about your process? Are guesswork, or slow, hand-sampling techniques hampering your operating efficiency? Why not put Foxboro to work analyzing your process stream continuously — automatically? Ask your nearby Foxboro Field Engineer for details. Or write Foxboro's Analytical Department for complete information. The Foxboro Company, 465 Neponset Avenue, Foxboro, Massachusetts.

Some of the analytical measurements Foxboro can make – pH • Oxidation-reduction potential • Dielectric constant • Amperometry • Conductivity • Viscosity • Boiling point rise.

FOXBORO

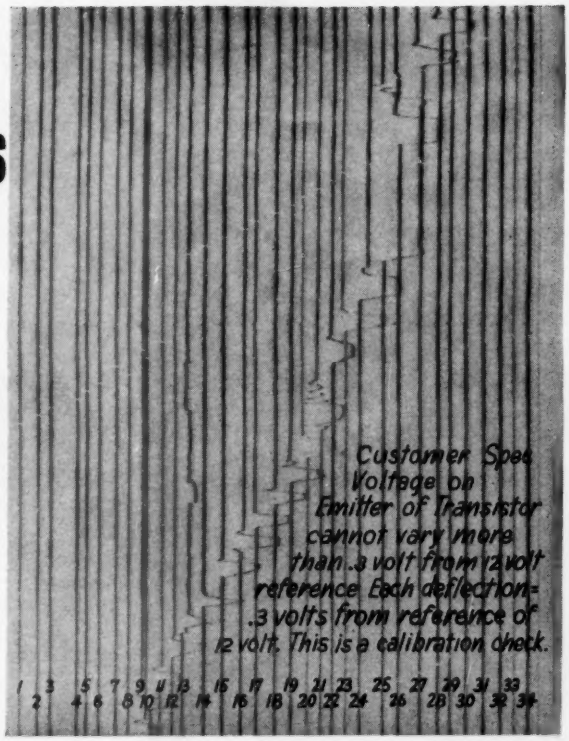
REG. U.S. PAT. OFF.

CIRCLE 31 ON READER-SERVICE CARD

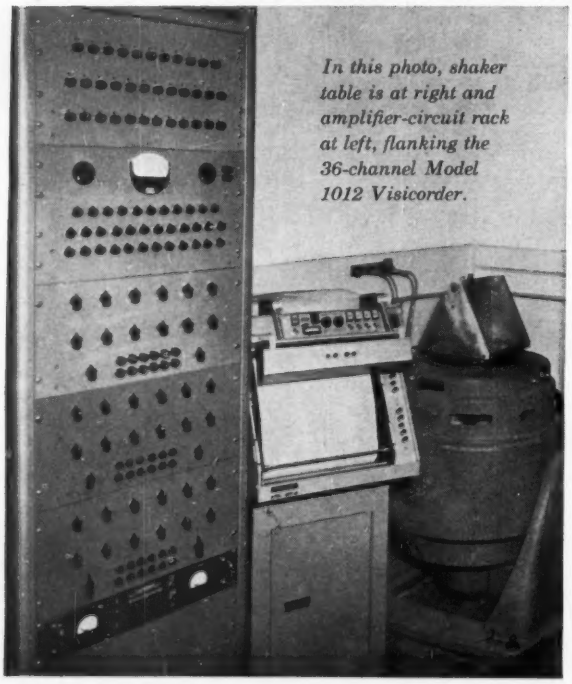
The VISICORDER records transistor torture

Transistors often have to work under incredibly severe environmental conditions. Production-testing them gave engineers at Honeywell's Semiconductor Division a chance to exploit the great versatility of the 36-channel Visicorder oscillograph Model 1012.

A certain order of transistors had to withstand vibrations of 10G at 10 to 2,000 cps without failing during the test or as a result of it. A standard test had been to measure the transistor's performance, next subject it to non-active vibration (not in any circuit), and then re-measure. This approach was obviously deficient as it did not reveal *operating* characteristics during test, nor did it disclose *intermittent*-type failures.



Unretouched record of vibration test on 36 transistors, each active in its own circuit during test.



In this photo, shaker table is at right and amplifier-circuit rack at left, flanking the 36-channel Model 1012 Visicorder.

The customer's quality requirements were stringent (AQL = .4%) and the large test sample required ruled out the use of an oscilloscope. The 3-hour test would have made a battery of scopes and operators necessary; transient defects would be missed due to eyestrain, fatigue, etc.

The Model 1012 Visicorder was chosen for the task as it simultaneously measures and records 36 channels of test information throughout the test period. The Visicorder instantly and directly records transients, no matter how random.

A Visicorder record like this is always a welcome supplement to your test data—your customer will be able to read it quickly and with full understanding. And it is a *permanent* record which *he* can show to *his* customer, if necessary.

For further information on how Visicorders can help to solve your instrumentation problems, contact your nearest Honeywell sales office without delay. Or write for Catalogs HC 906, 1012, 1108 and 1406, to:

Minneapolis-Honeywell, Heiland Division, 5200 East Evans, Denver 22, Colorado, SK 6-3681—Area Code:303

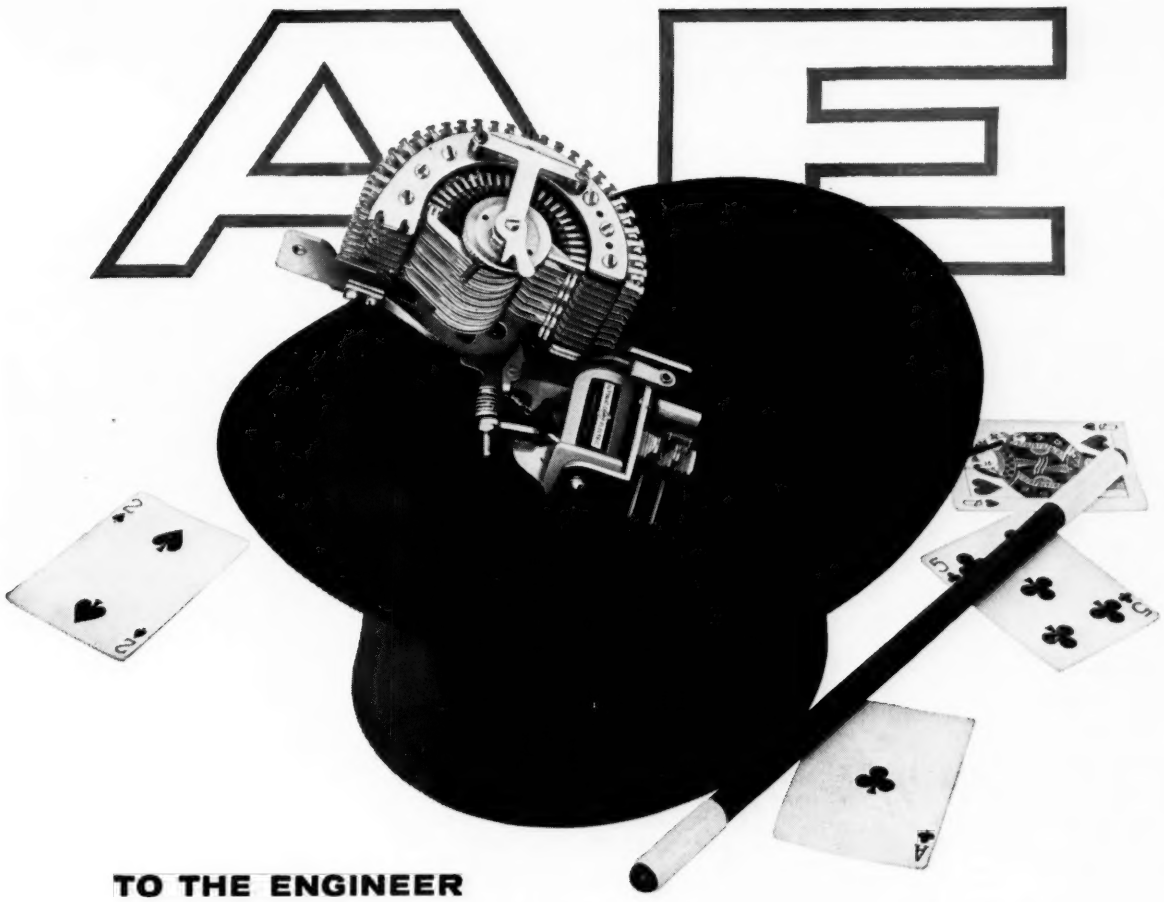
HONEYWELL INTERNATIONAL

Sales and Service offices in all principal cities of the world.

Honeywell

Industrial Products Group

CIRCLE 32 ON READER-SERVICE CARD



TO THE ENGINEER

who can use a little honest trickery

There's more than one way of skinning a cat —or making ideas *work* automatically. And AE has a bag-full.

That's because AE has had years of experience in making relays and stepping switches work wonders in automatic telephone exchanges—*and* in automatic control devices.

If you can use some down-to-earth magic in your designs, AE engineers will be glad to help. And you may well find that their suggestions can simplify the control package.

They can also show you why AE relays and stepping switches cost you less in the long run.

For instance, the AE Type 45 Stepping Switch, illustrated, has a free-floating pawl that never binds, never breaks, eliminates the necessity of ever readjusting armature stroke, does away with double-stepping or overthrow. And the switch usually outlasts the equipment it's built into!

You'll also be interested in knowing that AE is equipped to deliver completely wired and assembled control units designed to your specifications.

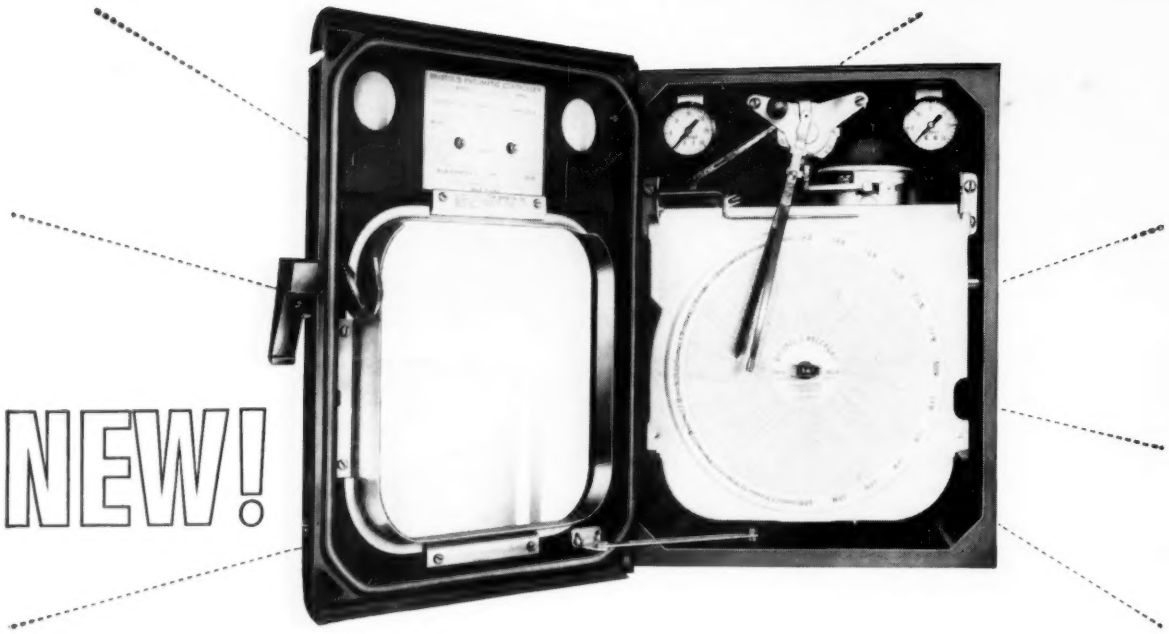
If you need timed impulses at equal or unequal time intervals, accurately spaced, send for more information on these high-speed, multi-contact rotary stepping switches. Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Ask for Circular 1698-J.

AUTOMATIC ELECTRIC

Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

CIRCLE 54 ON READER-SERVICE CARD



Bristol Series 532 A/D* pneumatic recording controller is outstandingly SIMPLE, RELIABLE, and STABLE

- **Simple modular design for ease of servicing**
- **High control stability for closer process control**
- **Designed for batch-type and continuous processes**
- **Proportional, proportional-plus-reset, and proportional-plus-derivative control models available**

Top control performance with maximum simplicity plus standard Bristol precision measuring elements—those are the key features of the Bristol Series 532 Recording Controller. The 532 uses the same renowned elements that have earned such a reputation for accuracy and dependability on other Bristol automatic controlling and recording instruments—perfected through wide experience and many years of development.

Self-contained modular design of the control unit speeds servicing. The whole modular unit, consisting of an aluminum casting with working parts made of stainless steel, Ni-Span C, and Neoprene diaphragms, can be removed by taking out only two screws and a link.

The die-cast aluminum instrument case (15¾ x 10¾ x 5¾ overall) presents a streamlined appearance and is completely dustproof and weatherproof.

Write for complete data on the new, versatile, economical 532 A/D. The Bristol Company, 113 Bristol Road, Waterbury 20, Conn., a Subsidiary of American Chain & Cable Company, Inc. 0.46

ACCO

CONTROL UNIT CHARACTERISTICS:

PROPORTIONAL BAND: 0-400% continuously adjustable, direct- or reverse-acting.

RESET: 0.1 to 100 repeats per minute.

DERIVATIVE: 0 to 10 minutes derivative time.

AIR PILOT: Non-bleed type.

PILOT CAPACITY: Over 3.0 scfm.

FREQUENCY RESPONSE: Essentially flat to 300 cycles per minute.

TEMPERATURE STABILITY: Less than 0.1% change in the output pressure for 90°F temperature change.

CHART: 8" diameter; wide variety available.

MATERIAL: Aluminum housing; 316 stainless steel internal parts; Ni-Span C feedback element.

RECORDING CONTROLLERS OFFERED FOR:

PRESSURE AND VACUUM: Ranges from full vacuum to 15,000 psi.

TEMPERATURE: Ranges from—100°F to +1000°F.

FLOW AND DIFFERENTIAL PRESSURE: With mercury-type manometer and dry-type differential unit.

LIQUID LEVEL: With bulb unit and mercury manometer and dry-type differential unit.

HUMIDITY: Zero to 100% relative humidity.

**Advanced Design*

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

VISIT US AT THE NATIONAL TELEMETERING CONFERENCE AT BOOTH TH 77-78.

CIRCLE 35 ON READER-SERVICE CARD

the world's most accurate and reliable potentiometer pressure transducer

The mating of advanced aneroid sensors with ultra-reliable film potentiometer elements, without intermediate linkages, results in:

- **INFINITE RESOLUTION**
- **LINEARITY TO 0.3%**
- **OUTPUT TO 40V WITHOUT AMPLIFICATION**
- **TOTAL ERRORS DUE TO HYSTERESIS, REPEATABILITY, TEMPERATURE AND VIBRATION: 0.2%**

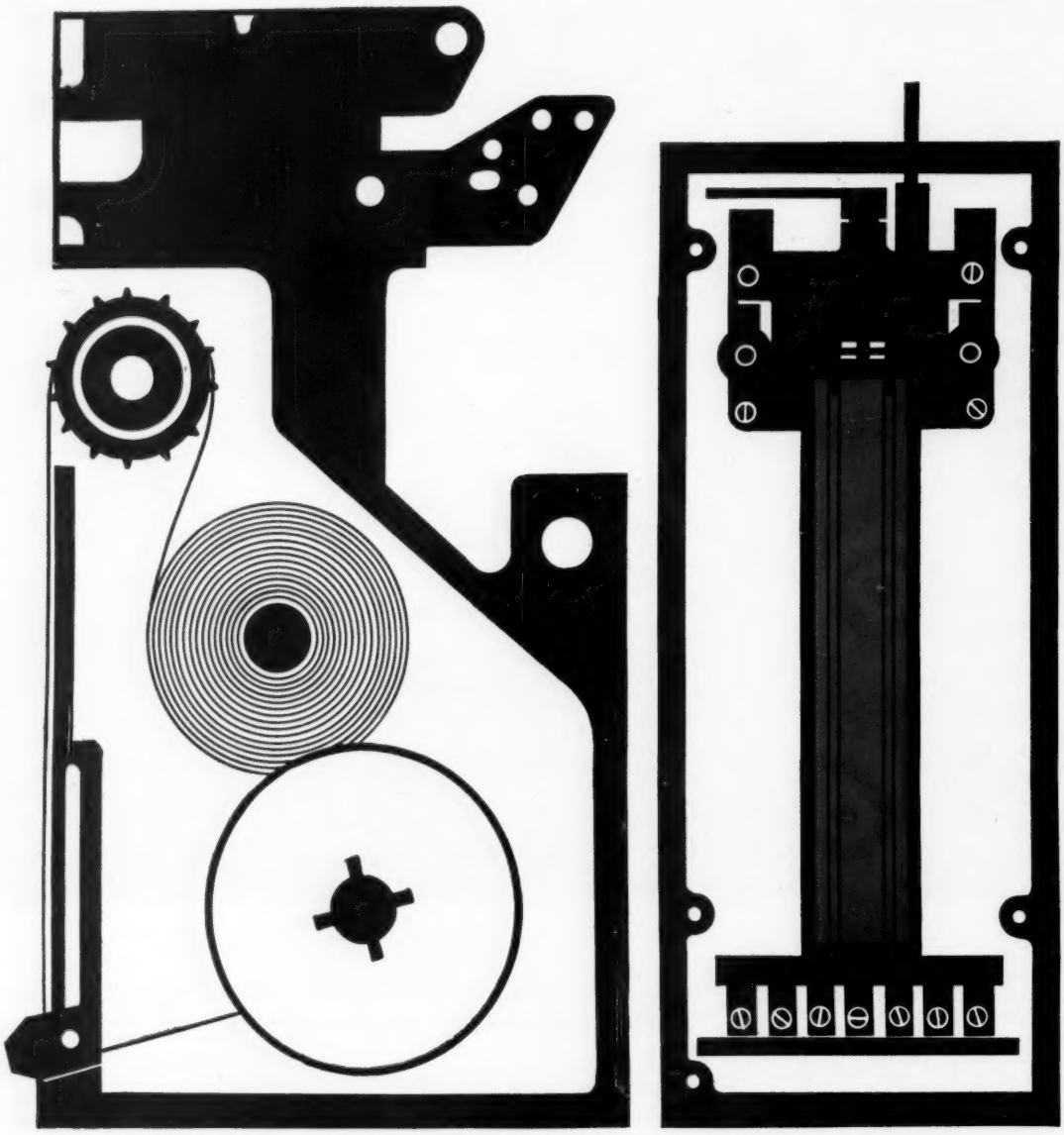
Send for Catalog

COMPUTER INSTRUMENTS CORPORATION
92 MADISON AVENUE • HEMPSTEAD, L. I., NEW YORK

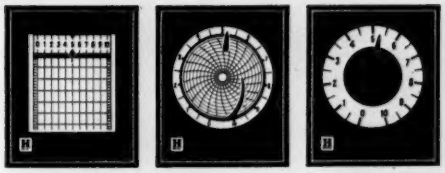
"first in film pots"
CIC

CIRCLE 36 ON READER-SERVICE CARD

ALL-NEW *ElectroniK 17* POTENTIOMETERS



NO SLIDEWIRE, NO SLIDEWIRE PROBLEMS. The unique *STRANDUCER* rebalancing element, an innovation in potentiometer design, replaces the conventional slidewire. It works on the proven strain gage principle and consists of four looped wire strands which form the resistance legs of a Wheatstone bridge. Both *STRANDUCER* and pen carriage are linked to the potentiometer balancing motor. A change in electrical input causes the balancing motor to change the tension—and electrical resistance—of the *STRANDUCER*. This in turn causes the balancing motor to rebalance the bridge, at the same time repositioning the instrument pen or pointer. The *STRANDUCER* is unaffected by corrosive atmospheres and has no contactors. It has unusually long life and infinite resolution and is unaffected when the instrument is subjected to ambient temperatures up to 130° F.



HAVE NO SLIDEWIRE, NO SLIDEWIRE PROBLEMS

Revolutionary STRANDUCER rebalancing element replaces slidewire . . . has unusually long life, infinite resolution*

Here is a totally new kind of potentiometer with a totally new kind of measuring system. The *STRANDUCER* rebalancing element replaces the slidewire, and sets a new high standard for potentiometer performance. The new *ElectroniK 17* potentiometers have a calibrated accuracy of $\pm 0.25\%$.

In addition, modular construction makes *ElectroniK 17* instruments easiest of all potentiometers to operate, convert and maintain. Complete interchangeability of components cuts service downtime and minimizes spare parts stocking requirements for these advanced potentiometers.

You can get *ElectroniK 17* instruments as strip or circular chart recorders or circular scale indicators. You can get electric contact control with up to 8 contacts. All control units are of convenient plug-in type.

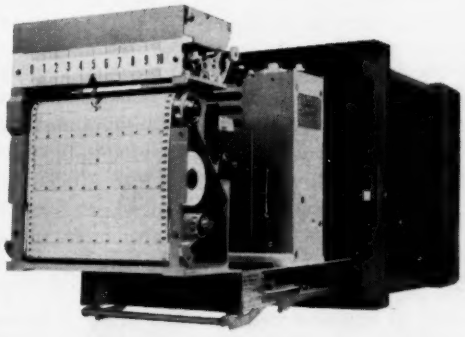
ElectroniK 17 is one of the great advances in potentiometry, and you should have all the eye-opening facts about this new class of instruments. For complete details, call your nearby Honeywell field engineer, or write MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.—In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell

First in Control

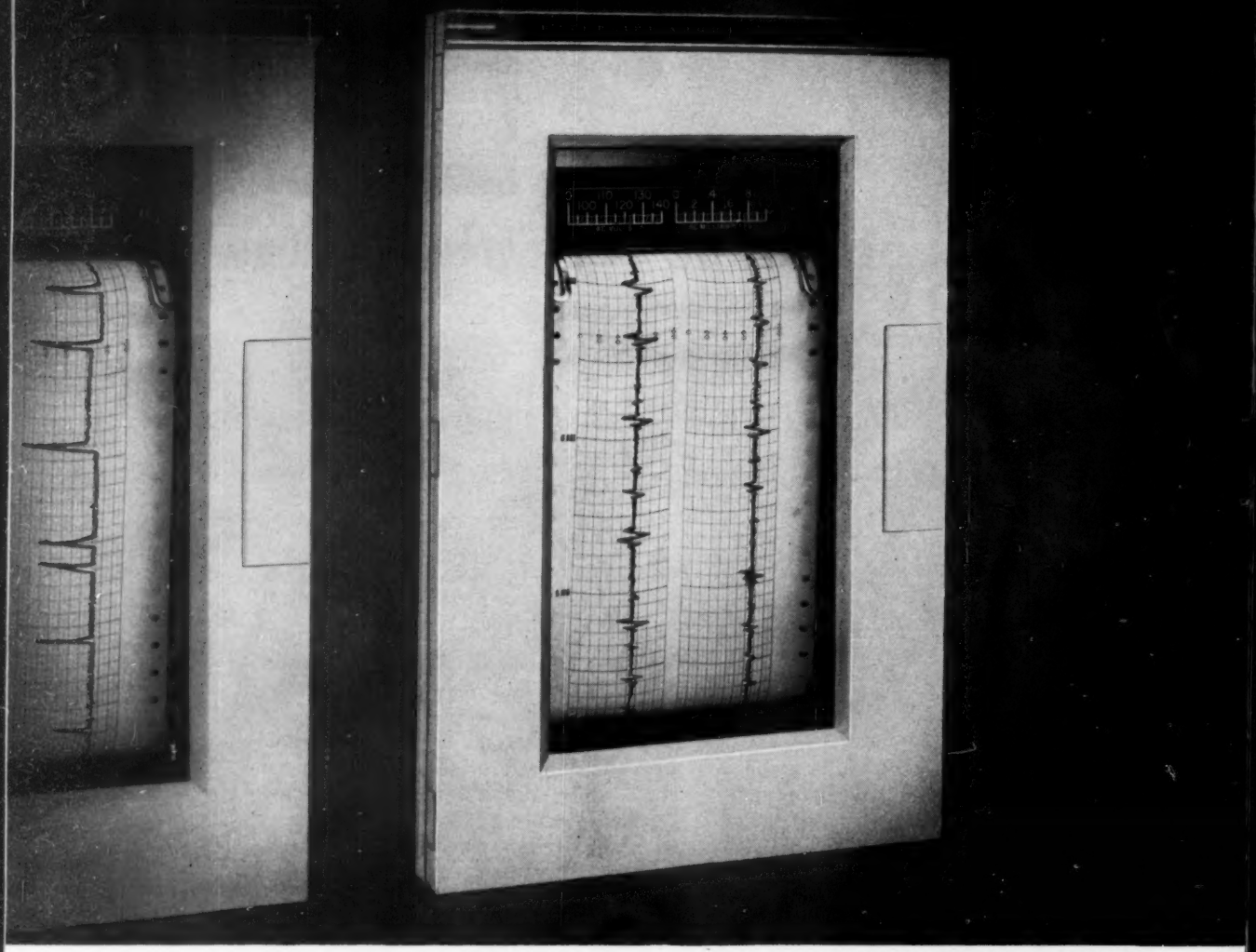
SINCE 1885

True modular construction saves you time, trouble, money. Three basic modules—case, display and drive—make up the *ElectroniK 17*. The case fits standard 19-inch relay racks. You can remove the door easily and without tools when converting from strip chart to circular chart or circular scale operation. You can pull out the chassis to the service position without tools, and without interrupting operation, or remove it completely. You can change chart speeds to ½ or 2 times basic speed (Standard chart speeds: 1, 2, 6, 10, or 60 inches per hour) by replacing quick-change drive gears. You change range and actuation simply by changing cards. Zener diode constant current supply eliminates battery problems. Up to 8 plug-in contact control modules provide for a wide variety of control possibilities.



HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

CIRCLE 37 ON READER-SERVICE CARD



Modern case designed by Raymond Loewy Associates.

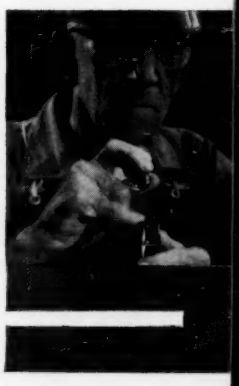
New "602" Esterline Angus Two-channel Recorder

This compact two-in-one instrument provides side-by-side synchronized graphs on a single six-inch-wide chart! Use it to check electrical circuits, to determine the quality of arc welds, to indicate proper settings for anodizing, to aid in medical diagnostic research, to provide a wide variety of other vital information. In fact, *any* two variants if expressed as current or voltage can be recorded simultaneously on this new two-pen instrument.

Price? Under $600. That's some $150 less than the cost of two graphic instruments previously required to do the same jobs!

Most important, the Esterline Angus Two-channel Recorder (which carries a unique-in-the-industry two year guarantee) is a product of 50-plus years of experienced craftsmanship—your assurance of dependable, trouble-free performance.

For more detailed information, write for new "602" Recorder descriptive sheet. Address: ESTERLINE ANGUS INSTRUMENT COMPANY, INC., Box 596G, Indianapolis 6, Indiana.



E. G. McDowell, Master Craftsman at Esterline Angus for 48 years.

Excellence in graphic recording for over 50 years—ESTERLINE ANGUS

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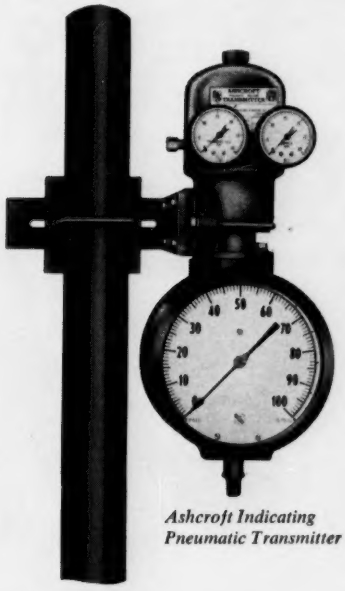
signal

ASHCROFT PNEUMATIC TRANSMITTERS give you a true primary and transmitted signal for indication or control



Ashcroft Indicating Pneumatic Transmitter

action

Now—detect with precision accuracy the slightest change in primary pressure or temperature. Transmit this signal quickly to your indicators or controllers. Ashcroft Pneumatic Transmitters do the job at lowest initial and operating costs.

Full-range, solid-front indicating and totally accessible nonindicating transmitters need no costly high-pressure lines, yet permit complete monitoring of processes in remote areas. For safety's sake, you get full indication even if the air is shut off.

Narrow-span Ashcroft Transmitters are expressly designed with highest sensitivity and repeatability for the most accurate primary signal feed to controllers. You get better control and purer, lower-cost final products.

Only in Ashcroft Pneumatic Transmitters can you get the wide choice of Ashcroft Duragauge Bourdon tubes or American mercury or gas-actuated sensing systems. You also get a time-proven, obstructionproof, force-balance, non-bleed replay for economical, maintenance-free 3-15 psi or 3-27 psi signal transmission. Both indicating and nonindicating *suppressed* types available.

Write for factful Bulletins 360 and 361 or ask your nearby Ashcroft Distributor to help you select the right transmitters and receiver gauges.

MANNING MAXWELL & MOORE INC. TRADE MARK

ASHCROFT PNEUMATIC TRANSMITTERS

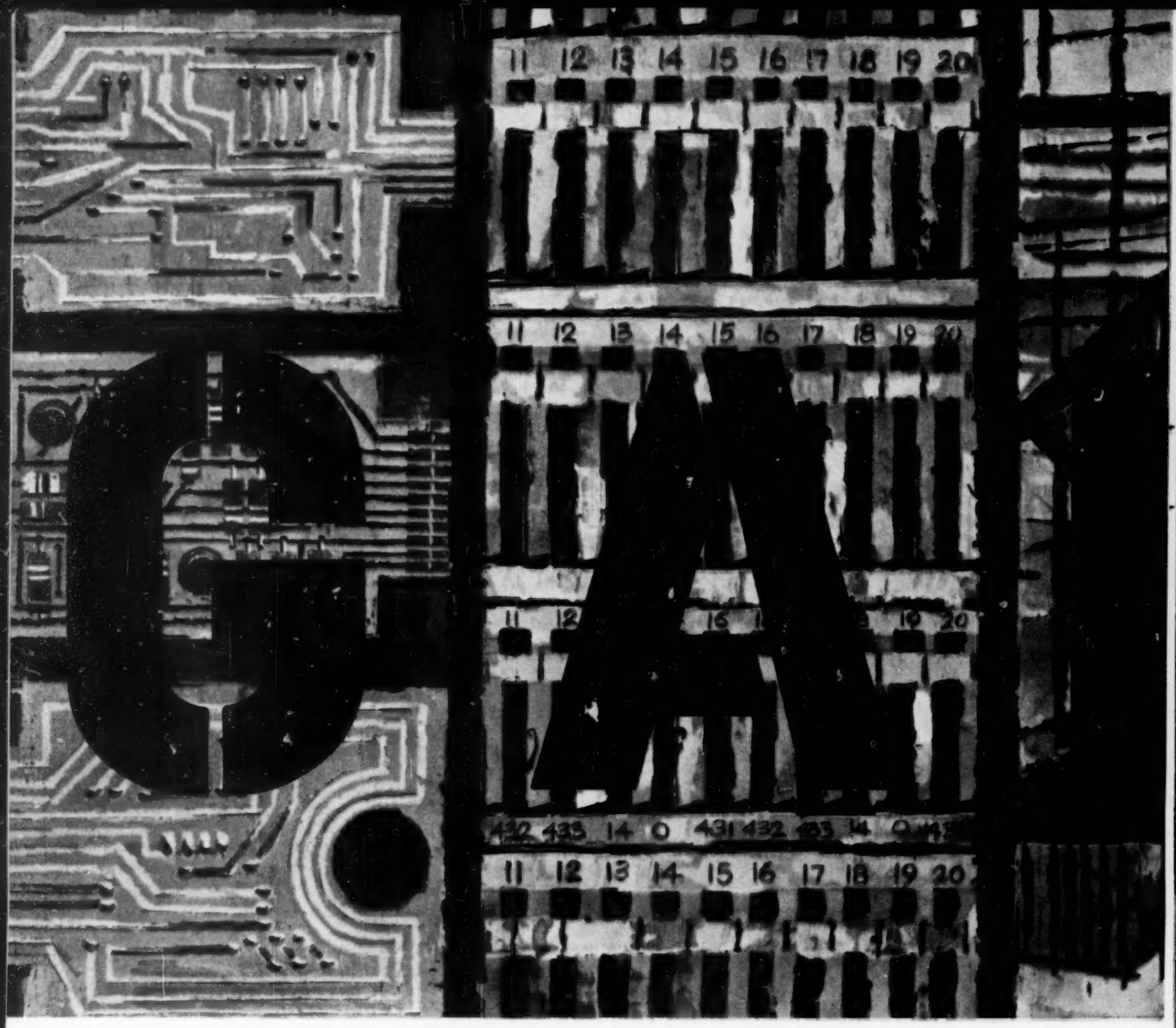
A product of

MANNING, MAXWELL & MOORE, INC.

Gauge and Instrument Division • Stratford, Connecticut

Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario
Latin America: Export Division, Chrysler Building, New York, N. Y.
Europe: Manning, Maxwell & Moore, S. A., Fribourg, Switzerland

CIRCLE 39 ON READER-SERVICE CARD



G Gathers automatically the information the operator needs to supervise the plant.

A Alarms off-limit quantities... automatically warns when an unsafe value occurs and logs all points exceeding pre-set limits.

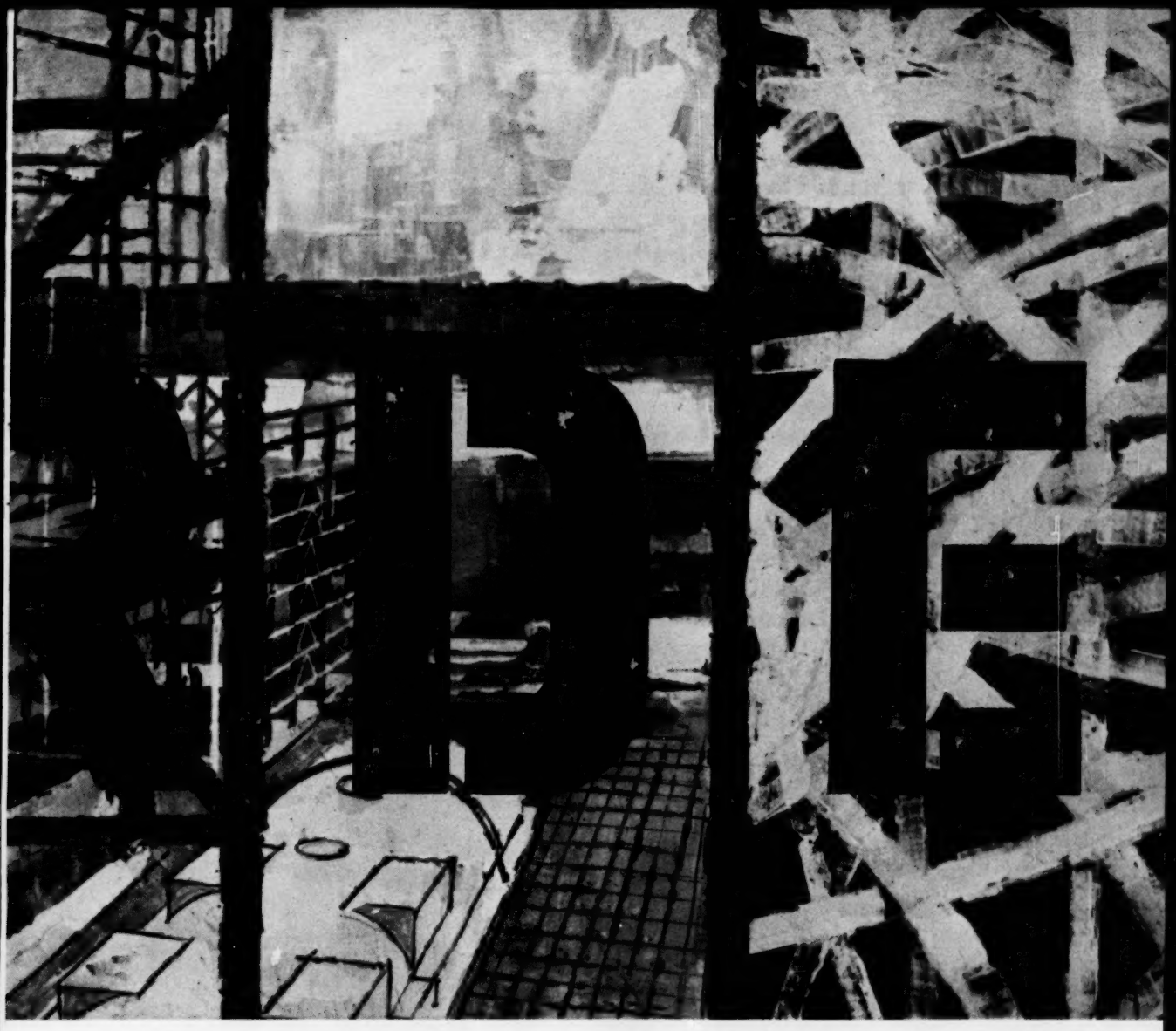
NEW GENERAL ELECTRIC COMPUTER SYSTEM

designed solely for electric utility steam power plant data processing

HERE'S HOW GENERAL ELECTRIC'S ADVANCED DESIGN SYSTEM LOWERS OPERATING AND MAINTENANCE COSTS...

GARDE is General Electric's process computer system designed especially to meet the problems and needs of electric steam plant data processing. The GARDE system gathers, alarms, reports, displays, and evaluates data from several

PCA-1



R Reports... automatically prepares a complete log of all operating conditions hourly or on demand.

D Displays... continuous visual display of any input or computed value that the operator chooses.

E Evaluates... over-all plant and key component performance hourly—or on demand.

hundred inputs located throughout the plant. It warns of abnormal deviations in those process conditions which cause equipment stress and inefficient operation. Early detection of these saves dollars in equipment maintenance and increases operating efficiency.

In addition, the GARDE system checks itself—detecting faulty sensors and other components. Its continuous reports are invaluable in periods of rapid operational changes. One of its provisions guides the operator through complex plant operating routines, helping him avoid errors and resultant equipment outage.

GARDE system evaluates these key plant operations: Boiler efficiency • Turbine Generator Heat Rate • Station Heat Rate • Correction of Heat Rates to Bogey Conditions • High Pressure and Intermediate Pressure Turbine Efficiency • Feedwater Heater and other Equipment Performance • Condenser Performance.

General Electric was able to design the GARDE system because it leads all manufacturers in process computer systems installed or ordered by the utility industry. The near-million man-hours of application and research in its design were spent in implementing systems for users. Out of this experience, came the GARDE process computer system.

.....

Investigate this newest development in data processing for steam plants—contact your nearest General Electric Apparatus Sales Office or Process Computer Section, Industry Control Department, P. O. Box 2918, Phoenix, Arizona.

In Canada, contact Canadian General Electric Apparatus Sales Department, Peterborough, Ontario.

Outside the U.S. and Canada, contact International General Electric, 150 East 42nd Street, New York 17, New York.

CIRCLE 40 ON READER-SERVICE CARD

Progress Is Our Most Important Product

GENERAL ELECTRIC

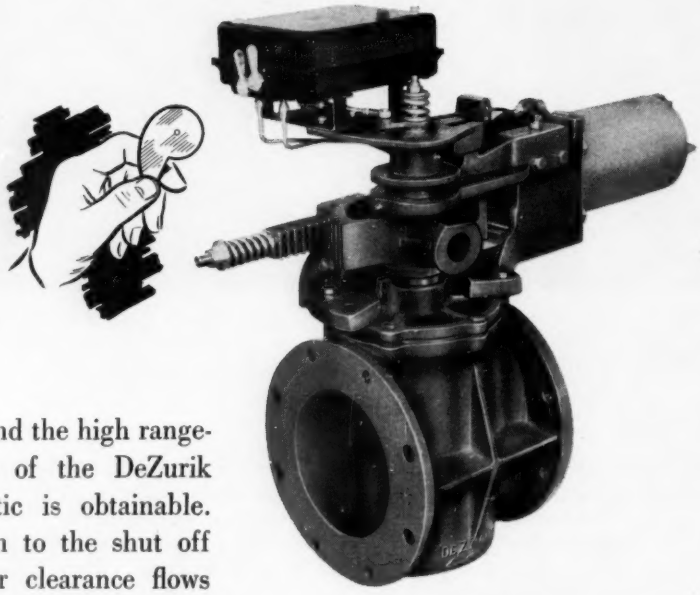
HOW DO YOU CHANGE THE CHARACTERISTIC IN YOUR PRESENT CONTROL VALVE?

(1)...SHUT DOWN THE SERVICE...

(2)...DISMANTLE THE VALVE...

(3)...REPLACE THE INNER VALVE...

WITH DeZURIK CONTROL VALVES THIS IS ALL YOU DO....



NO SERVICE SHUT DOWN, NO DISMANTLING OF THE VALVE...NO VALVE PARTS TO REPLACE!

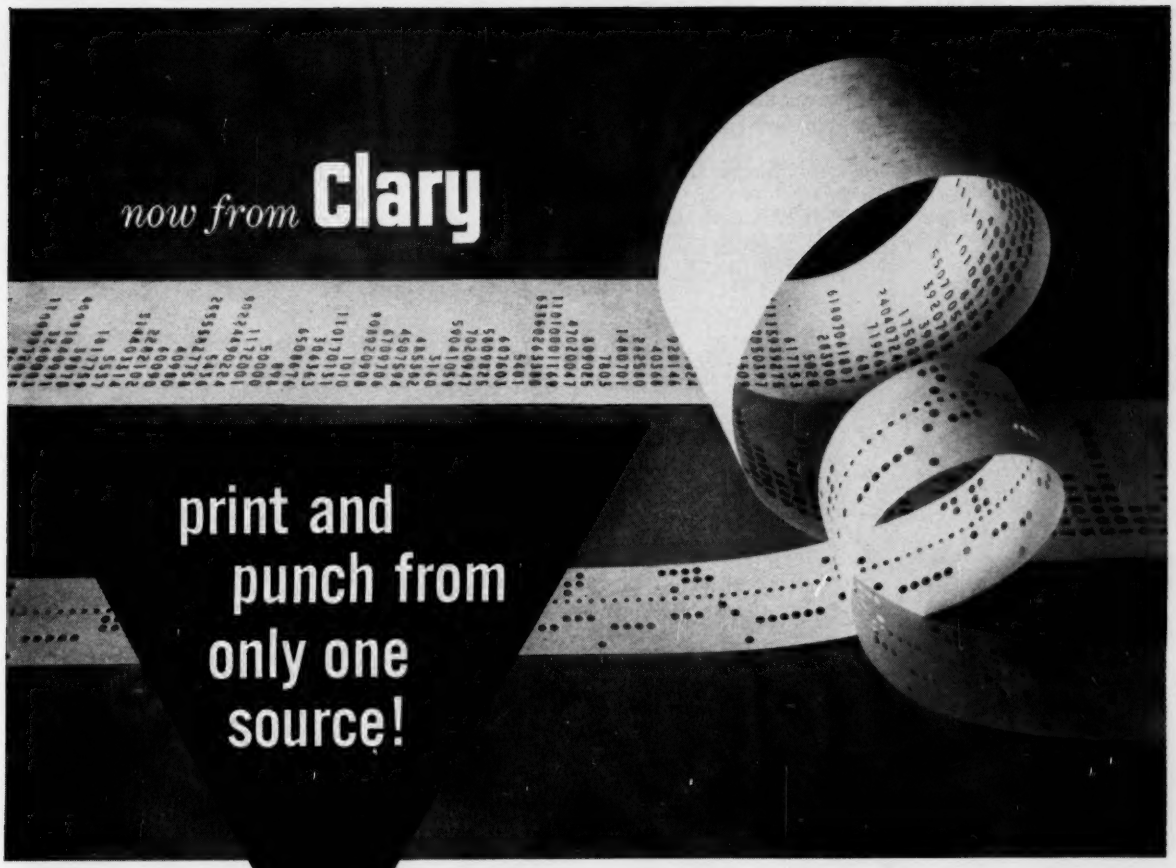
With this changeable cam—and the high rangeability inherent in the design of the DeZurik Valve—almost any characteristic is obtainable. The flow curve is useable down to the shut off position without the leakage or clearance flows which limit the rangeability in other types of valves.

For more information on DeZurik Control Valves, consult the DeZurik representative in your area, or write for Bulletin 150.

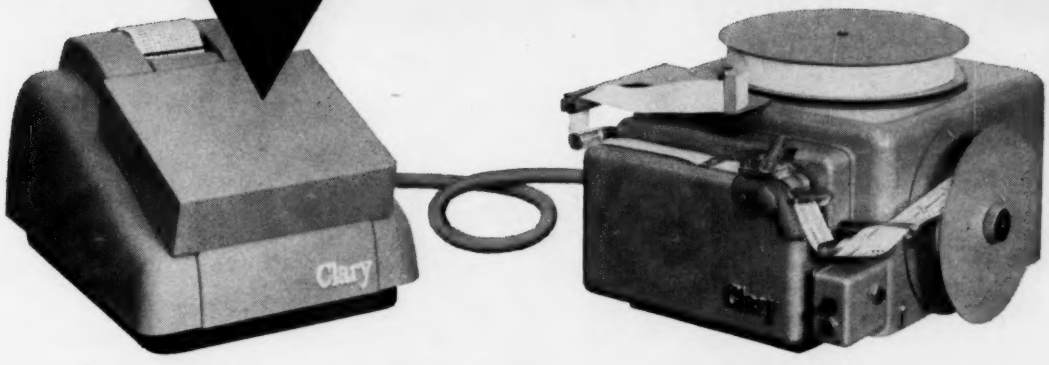
DeZURIK CORPORATION
SARTELL, MINNESOTA

CIRCLE 41 ON READER-SERVICE CARD

now from **Clary**



print and punch from only one source!



Now, with just *one* output from the data source, you can record information in reusable form *two* different ways – on printed tape, and on punched tape.

The secret of this simpler, faster, more economical recording method is Clary's special printer-perforator combination. This versatile unit prints out information from a wide range of data sources and records it on a "common language" punched tape.

The taped data can be kept for permanent records... mailed or directly teletyped to distant points... used as language for computers, process control units, and in other industrial applications.

For further information on this unit, or for help with any data-handling problem, just phone or write Clary.

Specification notes:
The printer used may be serial or parallel entry. The tape perforator will punch any number up to 8 transversely-spaced code hole channels, and the format is programmable.

Clary ELECTRONICS
San Gabriel, California

In Canada: Computing Devices of Canada, Ltd., Ottawa

CIRCLE 42 ON READER-SERVICE CARD

Bourns Offers Total Transducer Capability

NUMBER 14 — INSTRUMENT SERIES

Bourns offers you the full spectrum of transducer capabilities—research, development, production, quality control and environmental testing. From concept to completion, Bourns maintains rigid surveillance over the manufacture of every part of every instrument.

Need transducers for position? Pressure? Acceleration? Bourns can fill your order for 10 units or 1000, each instrument conforming exactly to your requirements, each instrument delivered with a detailed certificate of inspection and calibration. Unusual problem? Bourns engineers, credited with many of the industry's most notable innovations, will provide a solution that meets your specs, your budget and your deadline—a solution backed by an 11-year record of reliability in virtually every major U.S. missile and space program.

Write for new instrument summary brochure.

Pioneers in transducers for position, pressure, acceleration. Exclusive designers and manufacturers of Trimpot® potentiometers.

CIRCLE 43 ON READER-SERVICE CARD

Now! Get premium features in a DVM priced at only $940

Cubic Corporation announces the V-45 —the first low-cost digital voltmeter with premium features. Now industrial users can buy a top-quality, precision four-digit instrument at a price they can justify—only $940. Here are the premium features you get in a V-45:

Floating Input: Both sides of the input may be floated above or below ground. The floating input circuit provides more than 80 db rejection to 60-cps common-mode signals. A grounded input is also supplied.

Extended Range: A 10% extension is incorporated in each of the V-45's three ranges. Voltages up to 10.999 may be read on the 10-volt range; voltages up to 109.99 may be read on the 100-volt range; and voltages up to 1099.9 may be read on the 1000-volt range. Therefore, the operator need not constantly shift back and forth between ranges when reading close to the normal upper limit of a range.

Transistorized Logic and Drive Circuit: The V-45 DVM uses construction techniques representing the latest state-of-the-art, with all-transistorized circuitry driving reliable stepping switches.

Cubic manufactures a complete line of quality digital instruments, including a-c and d-c voltmeters, ohmmeters, ratiometers, scanners and printer controls. Write for literature to Dept. IC-104, Industrial Division, Cubic Corporation, San Diego 11, California.

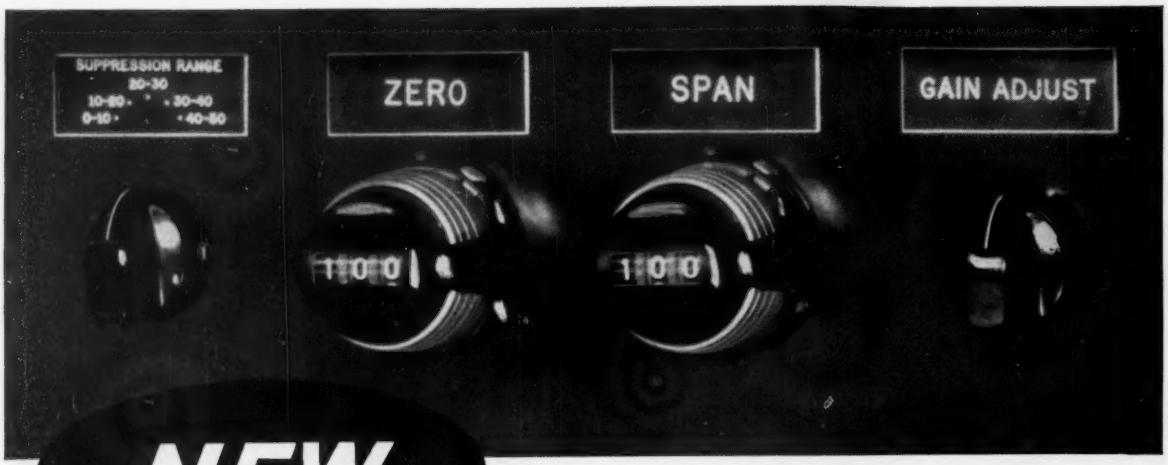
SPECIFICATIONS

MODEL V-45 DIGITAL VOLTMETER

Input Impedance: 10 megohms at balance.
Ranges: Manually selected, 10% extended range
Low ±0.000 to ±10.999 vdc
Mid ±00.00 to ±109.99 vdc
High ±000.0 to ±1099.9 vdc
Sensitivity: 1 millivolt
Sensitivity Control: Continuously variable from 1 digit to standby lockout.
Power Input: 105-125 vac, 50-60 cps, 25 watts standby, 30 watts operating.
Dimensions: 19" wide, 5¼" high, 14" deep, rack or bench mounting with dust-proof switch and bridge section.
Average Balancing Time: Less than 2 sec.

cubic CORPORATION

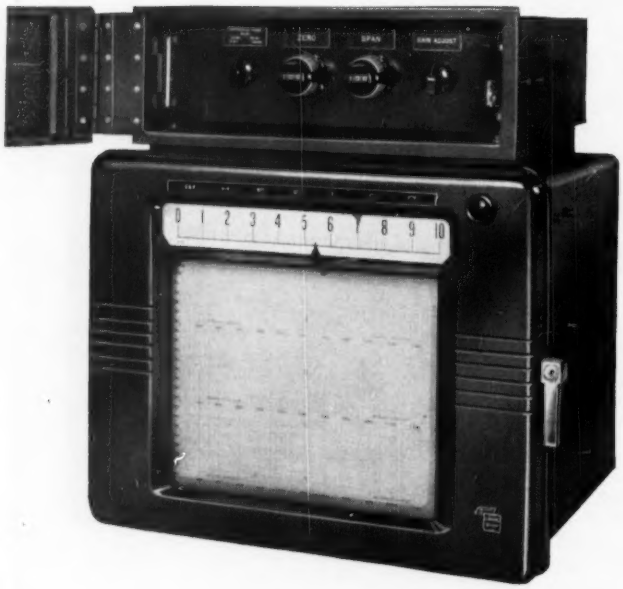
CIRCLE 44 ON READER-SERVICE CARD



NEW ... *through research by Barber-Colman*

Dials read out zero and span adjustment for MV potentials

Digital Dial Recorder/Controller For Span Adjustment or Zero Suppression



The Digital Dial Recorder/Controller saves time and gives you the ranges and flexibility unobtainable in fixed-parameter recorders. You can dial up to 50 MV of zero suppression by 10 MV step knob and calibrated 0-1000 readout counter. OR, you can dial any span from 0-.5 to 0-20 MV with counter calibrated 0-1000. *Changing the span does not affect zero settings; conversely, changing zero settings does not affect span.* A convenient amplifier adjustment knob permits gain settings. Zener diode constant voltage source assures accuracy even at .5 MV span . . . ½ of 1% overall accuracy. Control switches adjust over 100% of full range. Easy-access, swing-away design speeds change of charts, control forms, or components. Any Barber-Colman, Wheelco office will supply full data — contact one now.

BARBER COLMAN

BARBER-COLMAN COMPANY

Wheelco Industrial Instruments Division

Dept. Q, 1515 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. Q, Toronto & Montreal • Export Agent: Ad. Auriema, Inc., N.Y.

CIRCLE 45 ON READER-SERVICE CARD

POST ELECTRONIC PRODUCTS and CONTROL SYSTEMS

ASSURE:

RELIABILITY • ACCURACY
LOW MAINTENANCE • PRODUCTION CONTROL

Post's *proven* electronic counters and control systems are in widespread use throughout industry. Serving such diverse needs as batch counting, measuring, sensing or machine control. Post electronic products are ideal production aids.

Note these examples of Post's broad line of Electronic Products . . .

COUNTERS

SD-1T Outmodes mechanical counters. Will operate at speeds up to 100 units per second. Single 'count' registers on visual totalizer as each 10th. item breaks beam. Note: 12 place tube available for counting dozens or gross lots.

P-5 Preset counting of any desired 'batch' — 1-100,000 units. Other models available for 10,000 or 1,000,000 range. Direct 'batch' readout on all models from totalizer . . . quantity less than 'batch' shown directly on tube face (s).

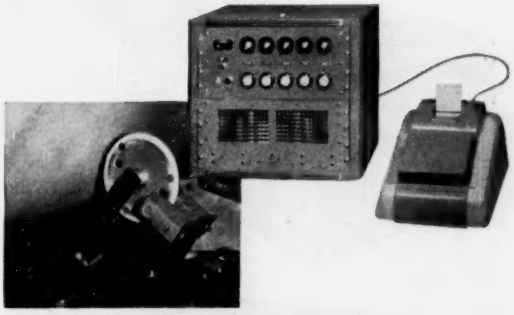
PW-5 PRESET Counter with BUILT-IN WARNING SYSTEM. Model shown will 'batch' count 1-100,000 units (inclusive) and warning selection dials may be set to energize a secondary control circuit, i.e., 'Batch' count desired 5000 . . . warning count desired 4900. When warning count reached, impulse may be given to flash light, operate solenoids for opening or closing feed gates, etc.

SENSING DEVICES

H-21-C A miniature, all purpose photohead. Ideal for limited space application. 'Head' not much longer than standard paper clip. Exciter lamp life 5000 hours. Utilizes photosensitive semi-conductor cell.

MH-2-P A new, compact magnetic switch in neat epoxy resin shell. . . . Magnetically operated as sensing device, the MH-2-P is capable of speeds up to 100 cycles per second — long life — no "bounce".

CONTROL SYSTEMS



LF-1A Lineal footage measurement, electronically . . . Capable of length measuring continuous production items, i.e., paper, wire, rope, ribbon, etc.
Features visual and printed readout.

**Representatives throughout the United States*
Request product literature today.

POST
ELECTRONIC PRODUCTS
Division of Reid Brothers Company, Inc.
12 LOTHROP STREET, BEVERLY, MASSACHUSETTS

Your special problems are earnestly requested!
Note: Complete line of production line counters available.
CIRCLE 46 ON READER-SERVICE CARD

	SD-1T
	P-5
	PW-5
	H-21-C
	MH-2-P
	LF-1A

Please send me product literature on the following:

NAME _____

TITLE _____

COMPANY _____

ADDRESS _____

HAMILTON STANDARD ANNOUNCES . . .

4 new static inverters specifically designed for aircraft and missiles

Hamilton Standard has developed a new line of 100-VA and 500-VA inverters that establishes an important increase in inverter reliability and performance. The units are specifically designed for airborne use. They possess extremely high overload and short circuit capacity and offer wide operating ambient temperature ranges. The basic design is modular and utilizes silicon transistors throughout. The packages are small, compact and deliver high over-all power-to-weight ratios.

AS MAIN OR STANDBY AC POWER SOURCE, these new inverters can now replace much of the rotary equipment presently in use on aircraft and missiles for supplying power to:

- **Gyros**
- **Radar**
- **Telemetry**
- **Instrumentation**
- **De-icing and other heating equipment**
- **Warning and emergency devices**
- **Communication equipment**
- **Guidance systems**

CHARACTERISTICS OF 100-VA and 500-VA STATIC INVERTERS

RATING PART NO.	100 va 555546	100 va 566480	100 va 566470	500 va 570250
Output Voltage (Nom.) Frequency	115 v 400±0.25%	115 or 200 v 400±1%	115 v 400±1%	115 or 200 v 400±0.25%
Phases	Three	Single or three	Single	Single or three
Transient Protection	Yes	Yes	Yes	Yes
Temp. Ranges	−55°C to 125°C	−55°C to 85°C	−55°C to 71°C	−55°C to 125°C
Input Voltage (Range)	18-29v dc	20-29v dc	20-29v dc	14-29v dc

SEND FOR YOUR COPY of this illustrated Static Power Conversion Guide. Clip coupon and mail to:
HAMILTON STANDARD; Electronics Department
Section 72, Broad Brook, Connecticut.

Name_____

Position_____

Company_____

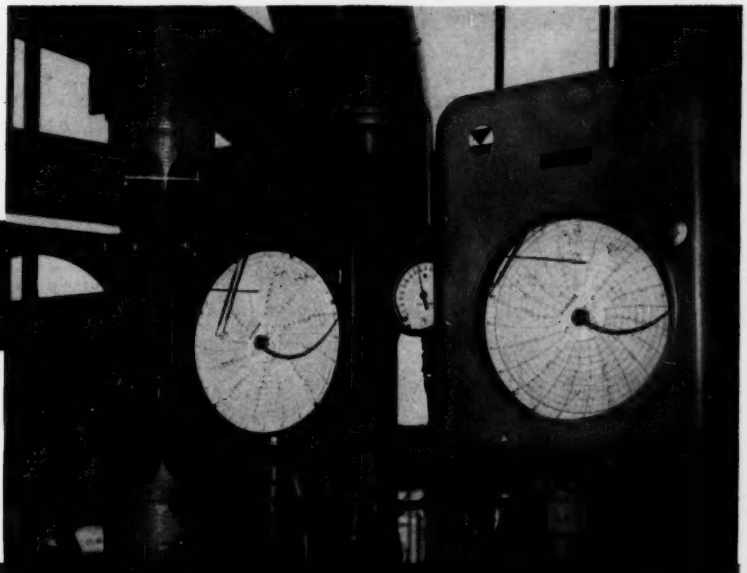
Address_____

UNITED AIRCRAFT CORPORATION

HAMILTON STANDARD DIVISION

ELECTRONICS

CIRCLE 57 ON READER-SERVICE CARD



American Integrating Orifice Meters, in a duplex setting, measure gas for boiler at Ft. Lauderdale power plant. These meters are equipped with a fixed gear train to provide a direct reading in cubic feet of gas at base conditions.

AMERICAN® instrumentation solves measurement problem for Florida Power and Light Co.

Florida Power and Light's Ft. Lauderdale power plant. Two of five boilers use 45 million cubic feet of gas per day on an interruptible basis, can consume up to 60 million cubic feet daily.

In each of the eight Florida Power and Light Co. power plants throughout the state, several boilers are fueled by natural gas. Florida Power and Light required a meter that provided a direct reading in actual cubic feet of gas used by each boiler. Measurements would then be transmitted by Telemetering to central data-gathering offices.

American Meter Company supplied a modified Integrating Orifice Meter with a counter reading in cubic feet of gas at standard base conditions that solved their unique measurement problem.

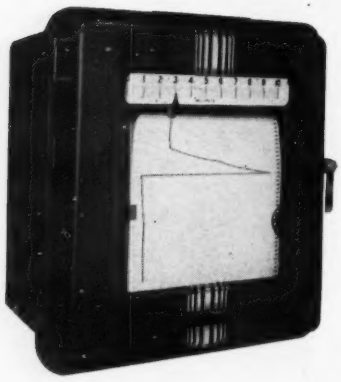
Whether your requirements are simple or complex, you can rely upon American Meter's 125 years of engineering experience to give you the dependable equipment you need for years of accurate, trouble-free measurement and control.

AMERICAN METER COMPANY

GENERAL SALES OFFICE: Philadelphia 16, Penna. • Albany Atlanta • Baltimore • Birmingham • Boston • Chicago Dallas • Denver • Houston • Kansas City • Los Angeles Minneapolis • New York • Omaha • Pittsburgh San Francisco • Seattle • Tulsa • Wynnewood IN CANADA: Canadian Meter Company, Ltd., Milton, Ontario • Calgary • Edmonton • Montreal • Regina Vancouver

GEM

CIRCLE 48 ON READER-SERVICE CARD



SAVE
Data Plotting
TIME
With Speedomax® G Millivolt Recorders

• Measuring a physical or electrical quantity that can be converted into d-c millivolts? Then you can eliminate costly, time-consuming point-by-point plotting with one of L&N's complete line of Speedomax G Millivolt Recorders. You may require: stocked 1 or 10 millivolt recorders for general research and testing; recorders with special millivolt ranges for particular applications; logarithmic recorders for non-linear measurements; and microvolt or medium high impedance recorders for special uses.

These listed specifications may help you determine which millivolt recorder meets your requirements.

1. STANDARD MILLIVOLT RECORDERS

(Normally available for delivery from stock)

MEASURING CIRCUIT—D-c potentiometer.

ELECTRICAL RANGE—0-1 or 0-10 mv.

DEAD BAND—0.15% of range.

ACCURACY RATING—±0.3% of range.

SPAN STEP RESPONSE TIME RATING —¼ or 1 second.

2. SPECIALIZED MILLIVOLT RECORDERS

MEASURING CIRCUIT—D-c potentiometer.

ELECTRICAL RANGE—Min. 0 to 1 mv; Max. 0 to 1,000 mv.

DEAD BAND—0.15% of electrical range, or 7 μv, whichever is larger.

ACCURACY RATING—±0.3% of scale span, or ±15 μv, whichever is larger.

SPAN STEP RESPONSE TIME RATING —¼, 1, 2, or 3 seconds nominal.

3. LOGARITHMIC MILLIVOLT RECORDERS

MEASURING CIRCUIT—D-c potentiometer.

ELECTRICAL RANGE — Min. starting point: 1 mv. Maximum full scale—1,000 mv.

LOGARITHMIC CALIBRATIONS—1, 2, or 3 cycles.

ACCURACY RATING—For 1 and 2 cycle logarithmic scale calibrations: ±0.7% x number of cycles. For linear scale calibrations (density, etc.): ±0.3% of scale span.

4. MEDIUM-HIGH IMPEDANCE RECORDER

MEASURING CIRCUIT—D-c potentiometer.

ELECTRICAL SPAN—Minimum span of 10 mv at resistances up to 100,000 Ω, 20 mv at 1 megohm.

INPUT IMPEDANCE—2 megohms.

EXTERNAL CIRCUIT RESISTANCE—As high as 1 megohm.

DEAD BAND—0.2% of electrical span.

ACCURACY RATING—±0.3% of electrical span.

5. MICROVOLT RECORDER

MEASURING CIRCUIT—D-c potentiometer.

ELECTRICAL SPAN—100 μv min., 2 mv max.

DEAD BAND—0.2% of electrical span.

ACCURACY RATING—±0.5% of electrical span including allowance for dead band and thermals.

For more information on this versatile line of Speedomax Millivolt Recorders, ask our nearest Sales Office for Data Sheet E-ND46(6) or write to Leeds & Northrup Company, 4955 Stenton Ave., Phila. 44, Pa.

LEEDS & NORTHRUP
instruments automatic controls • furnaces

CIRCLE 49 ON READER-SERVICE CARD

THE IMPROVED MINCOM SERIES CM-100 1.2 mc

At 120 ips the Mincom Series CM-100 now delivers 1.2 mc with the same reliability that has been typical of Mincom's 1-megacycle performance for years. 20% extended bandwidths also are obtained at CM-100's other five speeds (see table at right). Tape previously recorded at 1 mc can be played back on the CM-100 with improved reproduction. Consistently good pulse response, due to constant phase equalization at all speeds, enables this system to perform predetection recording/reproducing on an operational basis—in FM, FM/FM modulation, PCM and PCM/FM. Plug-in rack easily converts CM-100 from 7 to 14 tracks. Write for brochure and specifications.

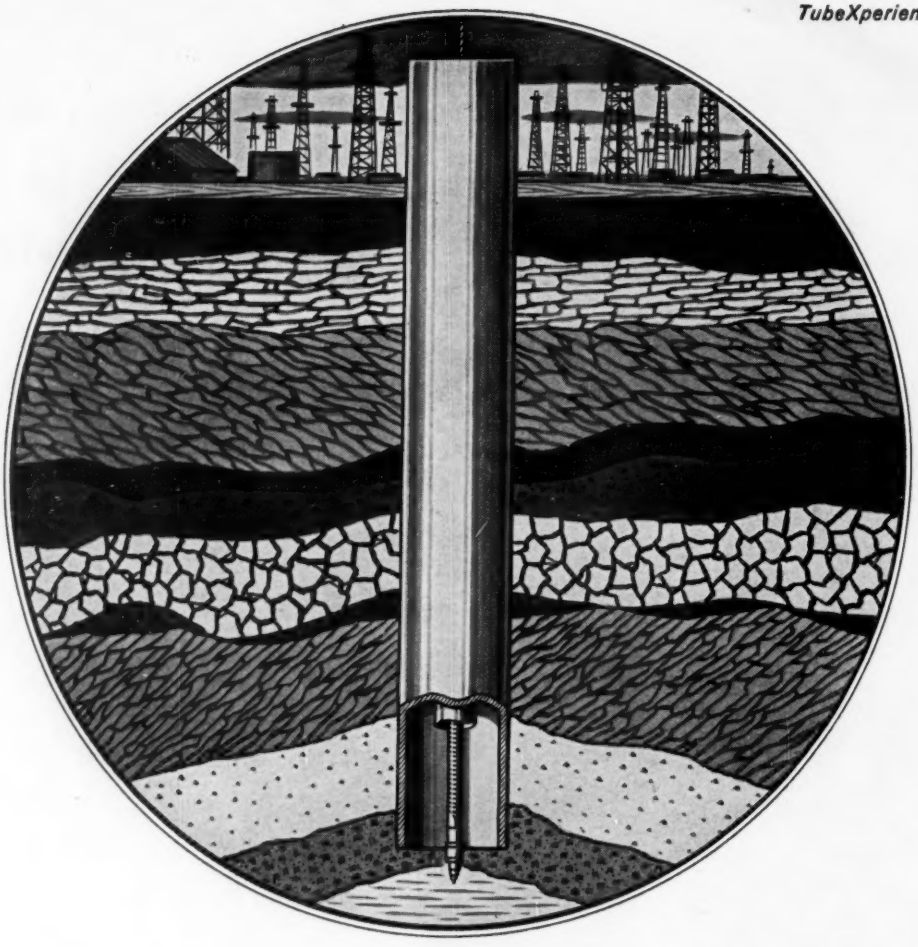
New Series CM-100 Frequency Response	
7½ ips— 75 kc	30 ips—300 kc
12 ips—120 kc	60 ips—600 kc
15 ips—150 kc	120 ips—1.2 mc

3M COMPANY ... WHERE RESEARCH IS THE KEY TO TOMORROW

MINCOM DIVISION MINNESOTA MINING AND MANUFACTURING COMPANY

2049 SO. BARRINGTON AVE., LOS ANGELES 25, CALIFORNIA • 529 PENN BLDG., 425 13th STREET N.W., WASHINGTON 4, D.C.

CIRCLE 50 ON READER-SERVICE CARD



Deep well pressure readings within .05% accuracy with help of Superior Ni-Span C* Bourdon Tubing

Accurate down-well pressure readings, indicating changes of only 1 to 4 psi at bottom-hole pressure of 2000 psi, are hard to get, but extremely important. They demand a pressure gage accuracy of at least 0.1% to make the vital engineering calculations based on them of any value.

To achieve this accuracy and better it, Superior was asked for help in selecting the Bourdon tube material for an improved bottom-hole measuring device. After careful study, its metallurgists recommended Ni-Span C nickel-chrome alloy for the Bourdon tubes. This material was chosen for its relative insensitivity to temperature changes, coupled with superiority in operating temperature, mechanical hysteresis, and elastic drift; also for its fatigue resistance and spring properties.

The customer followed the suggestion and now this gage, which is unique in bottom-hole pressure instruments for the reason that it utilizes a helix-wound Bourdon tube to transmit directly the effects of pressure to a recording stylus, is rated 0.1% accurate. In fact, with special care in operations and calibration, it can measure within .05% accuracy.

NI-SPAN C TUBING NOW STANDARD AT SUPERIOR

Ni-Span C redraw stock is now in inventory at Superior, available for immediate production in a range of sizes from .010 in. to ⅜ in. OD, up to .125 in. wall max., and from ⅜ in. to 1⅛ in. OD in wall thicknesses up to .035 in. max. Shaped tubing can be produced to customers' prints. Perhaps you have an application that can benefit from its unusual properties. Write for Data Memorandum No. 19. Superior Tube Company, 1968 Germantown Ave., Norristown, Pa.

**Registered trademark of International Nickel Co.*

Superior Tube

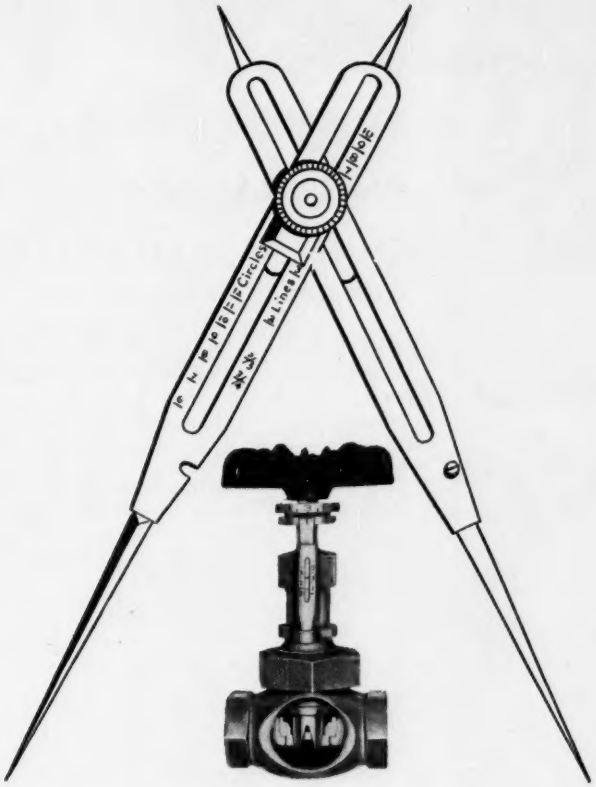
The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

CIRCLE 51 ON READER-SERVICE CARD



PROPORTIONER

controls flow to save for you

The V-port disc in all Hancock "Flocontrol" Valves insures proportional flow throughout the entire lift of the stem. They are valves that help you achieve uniform product quality through closer control, save steam and fuel on process work, and cut maintenance costs.

"3 in 1" valve design combines variable orifice with shut-off and micrometer dial and pointer. The valve opening can be set within 1/10 turn of the handwheel —you can duplicate all settings easily, instantly. No shut-off valve required—flow is in a straight line, with separate shut-off seating surface located away from the V-ports.

Hancock "Flocontrol" Valves are available in Bronze and Steel to meet the most demanding services. Ask your industrial supply distributor for details.

Hancock "Flocontrol" valves assure positive pinpoint control—eliminate all guesswork.

MANNING MAXWELL & MOORE INC. M&M TRADE MARK

HANCOCK "FLOCONTROL" VALVES

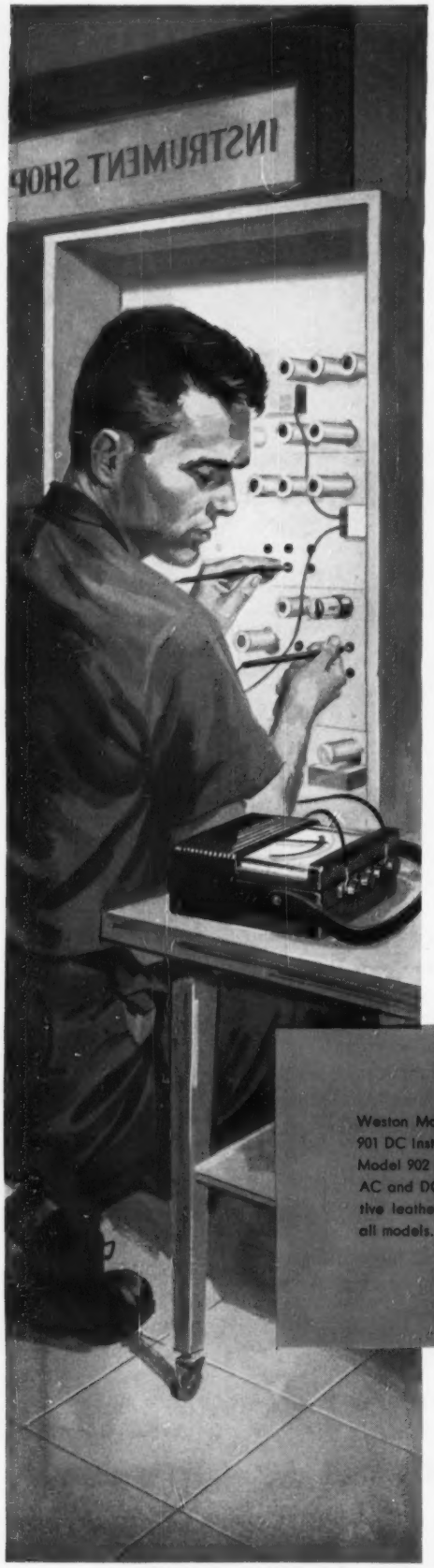
A product of

MANNING, MAXWELL & MOORE, INC.

Valve Division • Watertown, Massachusetts

Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario
Latin America: Export Division, Chrysler Building, New York, N. Y.
Europe: Manning, Maxwell & Moore, S. A., Fribourg, Switzerland

CIRCLE 52 ON READER-SERVICE CARD



THE FINEST INSTRUMENT FOR ALL-PURPOSE TESTING . . .

WESTON Model 901 Group
Now better than ever

Weston's matched line of Model 901 portables are well known for sustained accuracy and dependability under general test conditions. This modern group of AC and DC multi-range instruments consists of ammeters, voltmeters and wattmeters covering a wide range of measurement.

Designed for critical use, the Model 901 DC series is now accurate to 0.25%. Hand-calibrated mirror scales are combined with knife edge pointers to eliminate parallax errors. Widely-spaced markings on 5.5-inch long scales facilitate readability. The Model 904 AC series is now stocked in multi-range, frequency-compensated versions only.

Excellent for field use, these portables are housed in rugged plastic.

Other features include wide, shadow-reducing windows which are specially treated against electrostatic effects, and self-shielded mechanisms that offer positive protection against external magnetic influences.

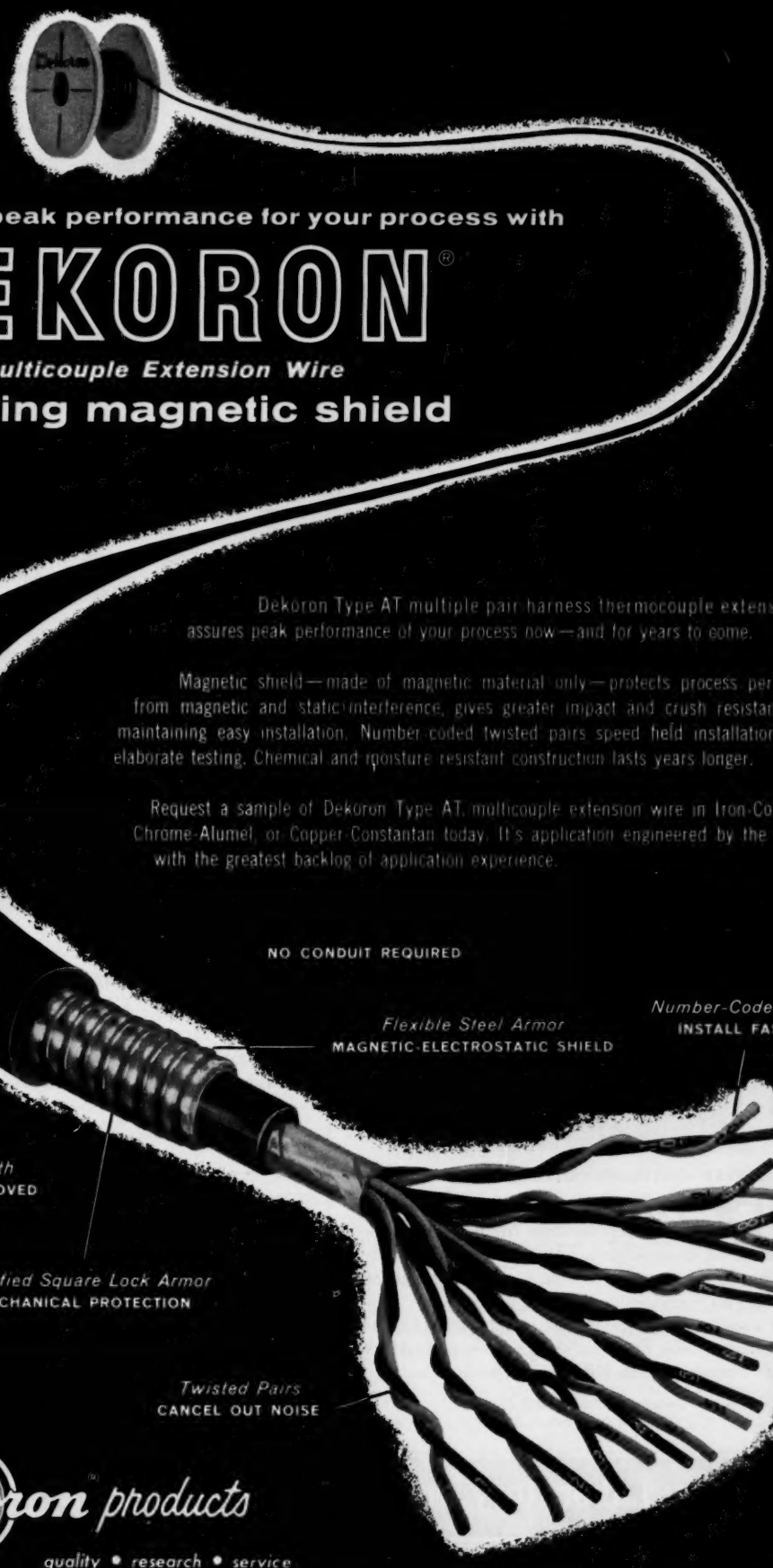
Call your Weston representative for complete information, or write for Catalog 06-203. Daystrom, Incorporated, Weston Instruments Division, Newark 12, New Jersey. *International Sales Division, 100 Empire St., Newark 12, New Jersey. In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ontario.*

Weston Model 901 Group consists of: Model 901 DC Instruments; Model 904 AC Instruments; Model 902 AC Rectifier-Types; and Model 905 AC and DC Single Phase Wattmeters. Protective leather carrying cases are available for all models.

DAYSTROM, INCORPORATED
WESTON INSTRUMENTS DIVISION
Reliability by Design

CIRCLE 53 ON READER-SERVICE CARD

CIRCLE 33 ON READER-SERVICE CARD→



Assure peak performance for your process with

DEKORON®

Cabled Multicouple Extension Wire

featuring magnetic shield

Dekoron Type AT multiple pair harness thermocouple extension wire assures peak performance of your process now—and for years to come.

Magnetic shield—made of magnetic material only—protects process performance from magnetic and static interference, gives greater impact and crush resistance while maintaining easy installation. Number coded twisted pairs speed field installation without elaborate testing. Chemical and moisture resistant construction lasts years longer.

Request a sample of Dekoron Type AT multicouple extension wire in Iron-Constantan, Chrome-Alumel, or Copper-Constantan today. It's application engineered by the company with the greatest backlog of application experience.

NO CONDUIT REQUIRED

Number-Coded Pairs
INSTALL FASTER

Flexible Steel Armor
MAGNETIC-ELECTROSTATIC SHIELD

Vinyl Outer Sheath
DIRECT-BURIAL APPROVED

Modified Square Lock Armor
MECHANICAL PROTECTION

Twisted Pairs
CANCEL OUT NOISE

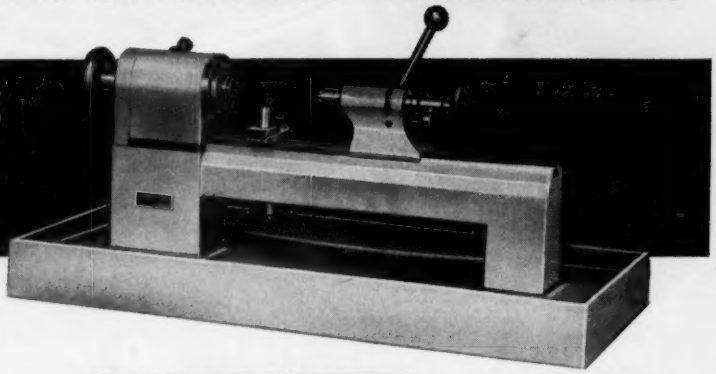
Dekoron® products

quality • research • service

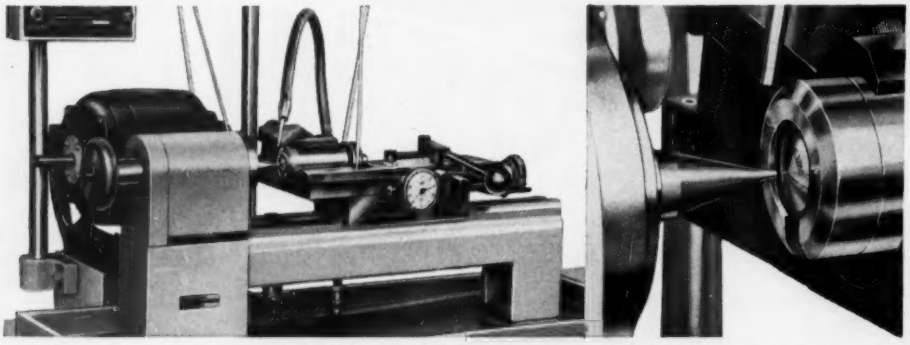
SAMUEL MOORE & COMPANY • DEKORON PRODUCTS DIVISION • **MANTUA, OHIO**

BIG NEWS FOR USERS OF INSTRUMENT LATHES

LEVIN® LATHES
PRODUCE SMALL INSTRUMENT PARTS MUCH BETTER



We present the latest in the series of Levin Instrument Lathes, a new model with a half inch collet capacity but with the same sensitivity and precision for which Levin Lathes are so well known.



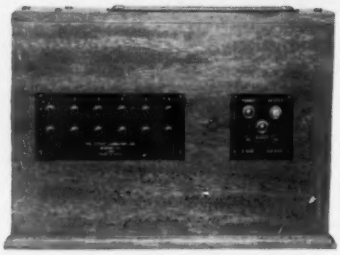
Here is a typical example of work which can be done in the new Levin ½" capacity lathe. A hole .002" in diameter is being drilled in a nozzle.

Send for literature describing the ½" capacity instrument lathe and accessories.

LOUIS LEVIN & SON, INC., 3573 HAYDEN AVE., CULVER CITY, CALIF.

CIRCLE 55 ON READER-SERVICE CARD

EPLAB
EPPLEY PRECISION VOLTAGE STANDARD AND ASSOCIATED EQUIPMENT



THE EPPLEY PRECISION VOLTAGE STANDARD

Consisting of six Eppley saturated standard cells, mounted in a Constant Temperature Air Bath for laboratories desiring to maintain a primary reference standard eligible for certification by the National Bureau of Standards. This combination provides an extremely reliable and accurate reference for use in calibrating unsaturated standard cells in accordance with specifications requiring "traceability" to NBS standards.

Send for Bulletin #1 (Standard Cells) and #12 (Constant Temperature Box)

THE EPPLEY STANDARD CELL POTENTIOMETER

A precision potentiometer designed especially for the rapid and accurate measurement of standard cell voltages. For use where routine calibrations must be made in quantity without sacrifice of accuracy.

Send for Bulletin No. 7

THE EPPLEY STANDARD CELL COMPARATOR

Provides a means of comparing accurately, to tenths of microvolts, the electromotive forces of two standard cells, by a measurement of the difference between the two forces. Designed primarily for the intercomparison of saturated, primary reference standards.

Send for Bulletin No. 11

The Eppley Laboratory, Inc. 2 SHEFFIELD AVENUE NEWPORT, R. I., U.S.A. **EPLAB**

44-1

CIRCLE 107 ON READER-SERVICE CARD

The Temperature Control Powered by the

IRREPRESSIBLE FORCE OF MERCURY—

for Accuracy with Rugged Dependability

All Partlow temperature controls are directly and positively actuated by mercury, the metal in liquid form whose reaction to changes in temperature is as predictable as it is powerful.

Unlike delicate electronic controllers, the mercury-actuated Partlow requires no outside power source. No amplifiers. No finicky levers. And no "babying"! With a Partlow you can be sure of getting accurate, dependable control even under extreme conditions of shock and vibration.

Mercury-actuation makes possible maximum design efficiency and simplicity too. The Partlow has fewer parts to go wrong. And fewer service problems (with less "down" time) should trouble occur. You can replace the thermal element of any Partlow control instantly, right at the job site, without recalibrating, fitting or factory adjustment.

Whatever the process or application, you'll find a Partlow temperature control to fit it dependably, economically, *precisely*. Mail coupon today for full details.

PARTLOW

TEMPERATURE CONTROLS

World Export:
Ad. Auriema, Inc., 85 Broad Street, New York 4, N. Y.

THE PARTLOW CORP., Dept. D-561
NEW HARTFORD, N. Y.

Please send condensed Catalog of Partlow temperature controls and allied equipment for industrial heating and refrigeration.

Name and Title.....

Company.....

Address.....

City and State.....

.....

CIRCLE 47 ON READER-SERVICE CARD

Here is Why!

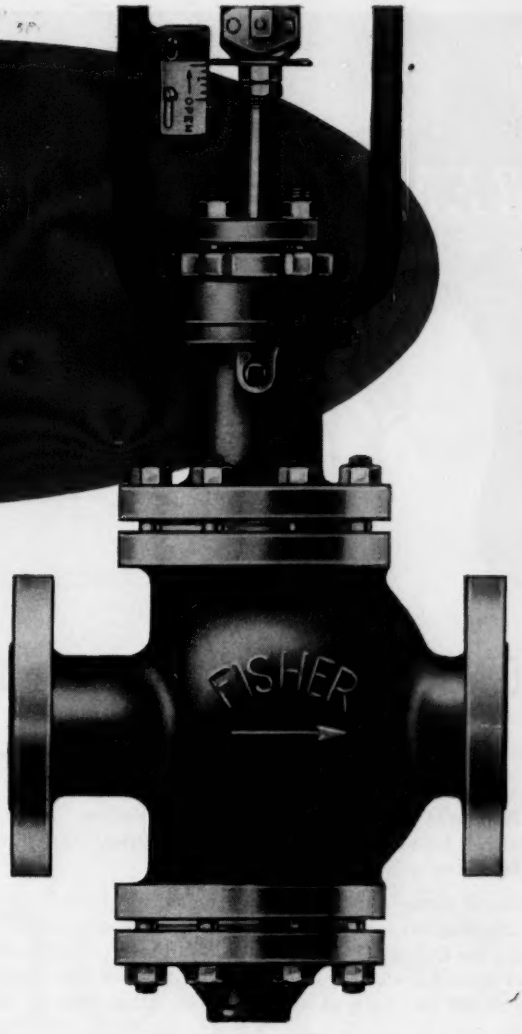
You can dispense with oil filters and dust filters when you install ®Nash® Clean Air Compressors. You can save the cost of maintaining these devices. You can greatly reduce instrument maintenance costs. For the Nash employs no internal lubrication, therefore no troublesome oil is in the delivered air. Moreover, air from a Nash is thoroughly washed and cooled as it passes thru the pump. Dust in the plant atmosphere, even fly ash, is immediately removed.

®Nash® Clean Air Compressors are simple, with only one moving element. No valves, gears, pistons, sliding vanes, or other enemies of long life and constant performance complicate a Nash. No aftercoolers are needed. You will find it profitable to investigate these pumps, now.

No oil filters.
No dust filters.
No internal lubrication to contaminate air handled.
No internal wearing parts.
No valves, pistons, or vanes.
Non-pulsating pressure.
Original performance constant over a long pump life.
Low maintenance cost.

NASH ENGINEERING COMPANY
370 WILSON, SO. NORWALK, CONN.

Saves up to 23% over cost of steel valves!



Fisher nodular iron control valves

● Nodular Cast (ductile) Iron valve bodies have higher yield strength than steel ● Ability to resist mechanical shock compares favorably to steel ● NCI valves have been tested at three times their rated pressure ● Corrosion resistance is as good, and generally better, than cast iron or carbon steel ● Effective in temperature ranges of −20°F. to +650°F. and pressures up to 1,000 psi. ● Shock or impact characteristics are comparable to steel ●

For more information, send for Technical Paper TM-5. Fisher Governor Company, Marshalltown, Iowa. Plants in Woodstock, Ont., Rochester, England. Butterfly Valve Division: Continental Equipment Co., Coraopolis, Pa.

NCI VALVE BODY SPECIFICATIONS

Body Styles—Double or single port globe bodies • **Body Sizes**—½ through 12" • **End Connections**—Screwed, ASA raised face or RTJ 150 to 600 psi flanges • **Plug Style**—Top and Bottom guided, V-Pup or Throttle Plug • **Pressure**—Temperature Ratings—Pressure 80% of corresponding steel flanges at a given temperature with maximum pressure up to 1,000 psi and maximum temperature 650°F. **Minimum Temperature**—Minus 20°F.

COMPARISON OF MECHANICAL PROPERTIES

	Cast Iron ASTM A126-B	Nodular Iron ASTM A395	Cast Steel ASTM A216-WCB
Tensile Strength, PSI	31,000 Min.	60,000 Min.	70,000 Min.
Yield Strength, PSI	———	45,000* Min.	36,000 Min.
Elongation, % in 2" Gage Length	NIL	15	22
Modulus of Elasticity, PSI	12—20x10⁶	24x10⁶	30x10⁶

*0.2% Offset

If it flows through pipe anywhere in the world ...chances are it's controlled by.....

FISHER® Controls SINCE 1880

CIRCLE 58 ON READER-SERVICE CARD

REMEMBER COLLAR BUTTONS?

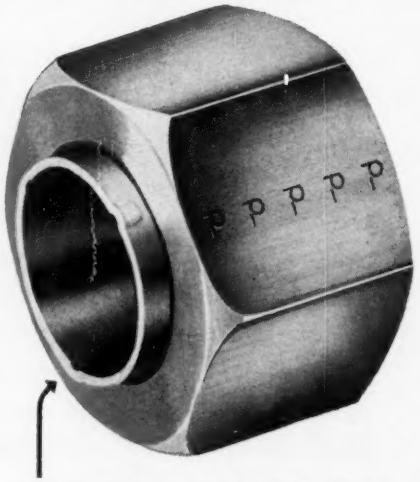
NOW **PARKER** HAS ELIMINATED A MORE SERIOUS ANNOYANCE ...LOST TUBE FITTING FERRULES!

A simple change in the design of Parker "Intru-lok®," the positive, bite-type Parker fitting for copper, aluminum or plastic tubing, has solved an age-old problem.

Small three- and four-piece tube fittings have long been a pain in the neck on applications where it is necessary to remove the nut from the fitting. The ferrule(s) fall out and promptly disappear. If and when found, they often get put in backwards. Sometimes they never get put back at all. Result, in either case: a leaking joint.

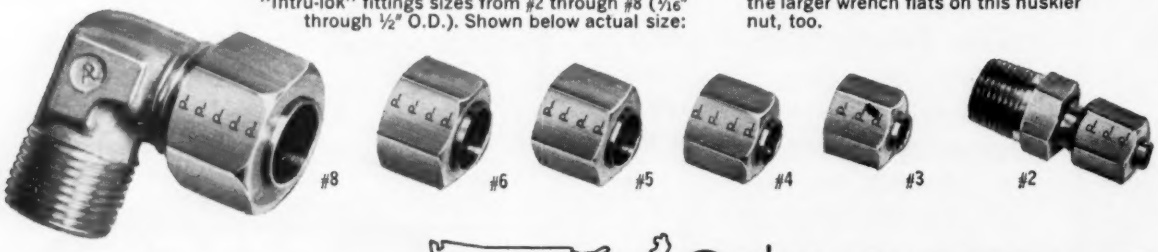
Now Parker has developed a snap-in, captive ferrule for "Intru-lok." You can take it out of the nut, "on purpose," but you can't drop it out accidentally.

You get all the leakproof safety of a three-piece fitting with positive "bite." You also get the convenience, the quick, easy assembly of a two-piece fitting. The easiest fitting to install has been made even easier. Write for new "Intru-lok" dimensions and prices today.



Three "detents" hold the "tail" of the new ferrule in the nut. Also, the larger hole in the nut makes tube bends closer to the fitting possible. Note the larger wrench flats on this huskier nut, too.

The new nut with captive ferrule is available on all "Intru-lok" fittings sizes from #2 through #8 (1/16" through 1/2" O.D.). Shown below actual size:



PARKER HANNIFIN CORPORATION

Parker FITTINGS AND HOSE DIVISION
17325 Euclid Avenue • Cleveland 12, Ohio
PNEUMATIC AND HYDRAULIC SYSTEM COMPONENTS
EUROPEAN DIVISION • PARKER-HANNIFIN N.V. • SCHIPHOL • THE NETHERLANDS

8278-PH

CIRCLE 59 ON READER-SERVICE CARD

accuracy

ASHCROFT DURAGAUGES measure pressure with precise accuracy no matter how severe the conditions of service

Ashcroft Duragauges are available in pressure ranges from 15 psi (or vacuum) minimum to 100,000 psi. Dial sizes: 4½" through 12".

sustained

The Bourdon tube in Ashcroft Duragauges is manufactured to precision standards of flexibility and mono-linked to the rotary movement. When pressure flexes the tube, the gauge pointer is always positively positioned, because it is mounted on the geared center shaft of the movement. Sustained high accuracy and long life are assured.

Choose your Ashcroft Duragauges made of components best suited to your needs. Eight Bourdon tube materials are available. Movement of stainless steel with nylon bearings and pinion gear for longest wear. Case materials: special aluminum alloy or tough phenol plastic.

The unique "Maxisafe®" Duragauge provides absolute protection to the viewer, plus easy and quick access to the mechanism. Your industrial supply distributor will help you select the best combination of components for your Ashcroft Gauge requirements. Phone him today or write for Catalog 300B.

MANNING MAXWELL & MOORE, INC. M&M TRADE MARK

ASHCROFT PRESSURE GAUGES

A product of

MANNING, MAXWELL & MOORE, INC.

Gauge and Instrument Division • Stratford, Connecticut

Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario
Latin America: Export Division, Chrysler Building, New York, N. Y.
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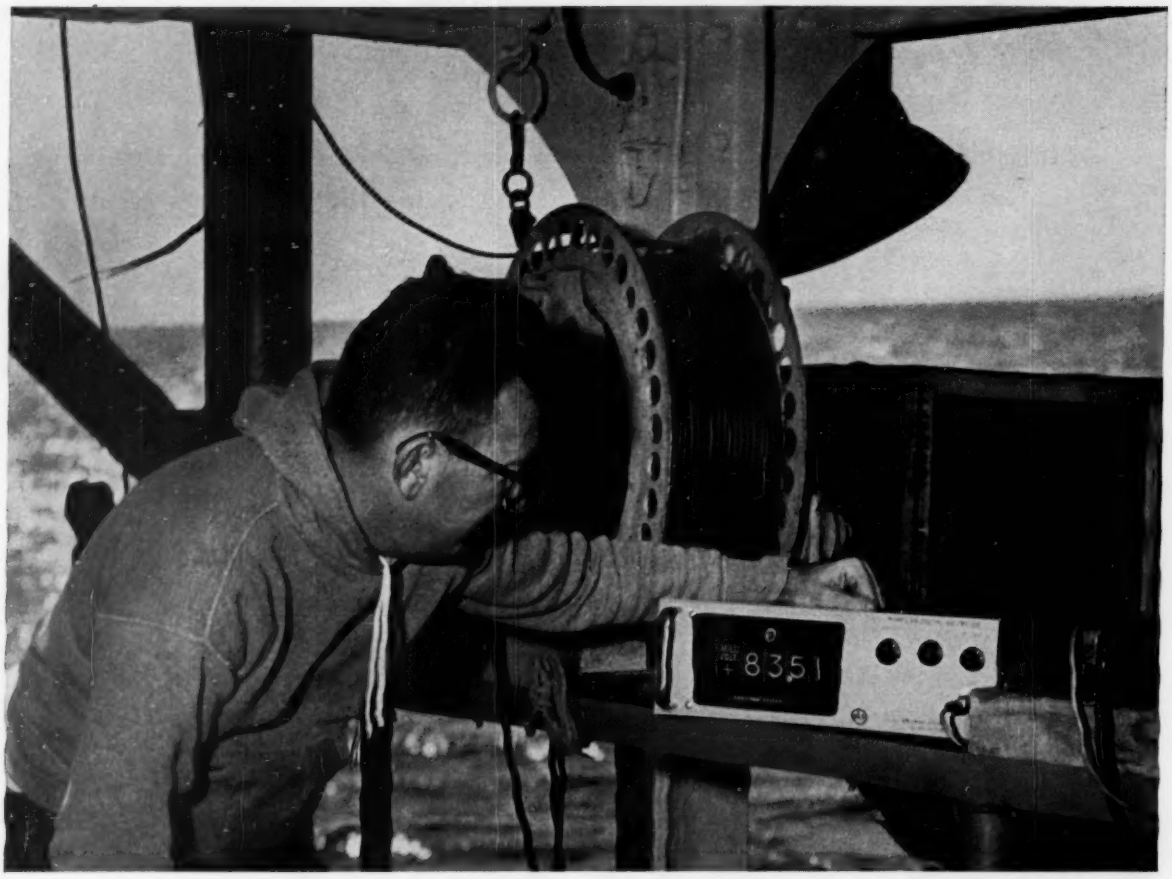
CIRCLE 60 ON READER-SERVICE CARD

Measuring News from NLS



NEW WAY TO MEASURE MILLIVOLTS

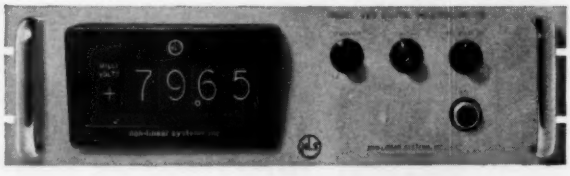
aboard ship, in the lab, on the production line

A faster, more precise method for making low-level DC voltage measurements is now provided by Non-Linear Systems, Inc., for scientific, industrial and military applications. The new, single-package NLS V60 Digital Millivoltmeter is a full 4-digit instrument that averages 80 measurements per minute for such applications as strain gage and thermocouple measurements, calibrating millivolt devices, process monitoring, and semiconductor research and testing. Because it's a digital voltmeter, the V60 can be read at a glance from close or afar in total darkness or sunlight, without parallax error.

The V60 features ±0.01% precision (ability to repeat readings within close limits) — a degree of precision unattainable from pointer meters, strip chart recorders, or combination of a digital voltmeter and preamplifier. Accuracy is ±0.1% of reading or ±10 microvolts. Range is ±00.01 to ±99.99 mv. A scale factor control allows the V60 to display its readings directly in units of pressure, weight, length, strain, stress, speed, etc. Input impedance is 10 megs at balance. Input terminals are completely isolated from ground, making AC and DC common mode rejection extremely high.

Please contact NLS for additional information on the V60 or any other NLS digital voltmeter.

V60 complete $1,625



non-linear systems, inc. *Originator of the Digital Voltmeter*
DEL MAR, CALIFORNIA

CIRCLE 61 ON READER-SERVICE CARD

THOMAS A.

EDISON

omniguard system . . .

guards critical temperatures for Con Edison

Con Edison's power generating station in Astoria, Long Island, one of the largest of its kind in the world, supplies one-eighth of the power consumed by New York City's millions. An installation as vital as this naturally requires the utmost protection to insure efficient, uninterrupted operation—around the clock, around the calendar. And this is where Thomas A. Edison's OMNIGUARD system provides such an important contribution.

The bearings of Con Edison's auxiliary equipment, ranging from main boiler feed pumps to coal pulverizing mills, are monitored by Thomas A. Edison resistance temperature detectors which are connected to Omniguard monitors located in the main control room. If any one of the 200-plus bearings monitored begin to overheat, an alarm is sounded instantly, the trouble area is identified on the Omniguard panels, and prompt corrective action is taken. Thanks to Omniguard, trouble is detected *before* damage can be done—which not only increases bearing life but slashes Con Edison's over-all maintenance costs as well.

Any industry can enjoy the complete, continuous protection that Omniguard provides. For complete information on your particular requirements, call or write:

Thomas A. Edison Industries
INSTRUMENT DIVISION
41 LAKESIDE AVENUE, WEST ORANGE, N. J.

CIRCLE 62 ON READER-SERVICE CARD

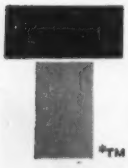
THE EQUIPHASE* TRIPLE-POINT-OF-WATER CELL

a convenient standard for establishing a fixed temperature reference point.

EQUIPHASE Triple-Point-of-Water Cell establishes a reference temperature of 0.01°C with guaranteed accuracy of 0.0005°C. Unaffected by atmospheric pressure, contamination-free, easy and convenient to use. Just 17" high, 8" diameter.

This new laboratory standard establishes the precise point, 0.01°C, where ice, water, and water vapor coexist in equilibrium. The reference temperature point produced by the Equiphase Cell is accurate within 0.0005°C and may be quickly established with a minimum of technique or set-up.

The Equiphase Cell's accuracy cannot be easily duplicated with an ice bath. The triple-point-of-water is a physical constant — so precisely reproducible that it has been recently designated as a defining fixed point for the International Practical Temperature Scale of 1948 by the General Conference on Weights and Measures.



Reliability? Ease of use? Reasonable price? You get all these as well. But even more important — if you must have accuracy, this must be your standard.

Please write today for complete information.

*TM

To put the sure in measurement

TRANS-SONICS, INC.

BURLINGTON, MASSACHUSETTS

CIRCLE 69 ON READER-SERVICE CARD

Reader Inquiries

Indicator Light

Instrument Design Engineer seeks small waterproof neon-lamp type indicator light. Must meet military environmental requirements for flight line test equipment. Lamp bulb to be smaller than the NE-51. A-6118

Furfural Analysis

Process engineer wishes to make continuous analysis of lubricating oil for furfural content in the range of 0.005 to 0.5% by weight. Various viscosities are involved. A-6117

Temperature Control

Reader in France wishes to build wire quenching apparatus (water or liquid introgen) and needs temperature control of 1° in 1000°C. Would prefer simple brilliance control. A-6116

Blood Flow

Physician at medical center, investigating sickle cell diseases, wishes information on photoamplification and photography of conjunctival blood flow. A-6119

Electrical Anesthesia

Senior surgeon at hospital is interested in apparatus for electrical anesthesia. A-6120

Electromyography

Medical doctor requests information on equipment for electromyography. A-6121

Electrocardiograph

Professor of physiology seeks EKG with "greater sensitivity" for blood pressure research. A-6122

Foetal Electrocardioscope

Hospital physician is interested in circuitry for an electro-cardioscope to record foetal electrocardio impulses. A-6123

Micro Blood pH

Medical technician of hospital is interested in *micro methods* to determine blood pH in the range of 6.8 to 7.8. A-6124

Oxygen and CO_2 Analyzer

Professor for ear, nose, throat at School of Medicine seeks apparatus to determine oxygen content (also CO_2 content) in situ, in ear, nose, and sinus cavity (without removing sample) to determine if sinuses have a respiratory function by measuring oxygen absorption. A-6125

PO_2—PCO_2—pH

Chief of cardiology at hospital wishes to measure PO_2, PCO_2 and pH by methods other than Riley Bubble or pH meter. A-6126

Blood Flow

Doctor in department of surgery of hospital seeks apparatus to measure accurately blood flow in medium and smaller sized arteries. A-6128

INSTRUMENT DAVIS DIVISION

GAS ANALYSIS INSTRUMENTS

Continuous and Portable units

✓ **PARAMAGNETIC OXYGEN MEASUREMENT**

Detects oxygen content of gases. Simple non-electronic circuit. Fast response — 95% reading in 15 seconds. Ranges from 0-5% O_2 to 0-100% O_2. EXPLOSIONPROOF CONSTRUCTION AVAILABLE.

✓ **PARTS-PER-MILLION GAS DETECTION**

Measurement of P.P.M. gas concentration. Used in air pollution studies, contaminant control, detection of toxic gases and vapors. Compact units for field surveys as well as universal mounting cabinets and self-standing cubicles.

✓ **COMBUSTIBLE GAS ANALYZERS**

Complete diversified line of systems for detection of combustible gases and vapors in work areas; litho and coating oven atmosphere control; etc. Control of combustibles in inert gas streams.

✓ **THERMAL CONDUCTIVITY ANALYZERS**

Measurement of concentration to one gas component in a mixture of gases, utilizing sensitive filaments as the detector. Applicable for determination of: H_2 in O_2. N_2 mixtures; Argon in air; hydrogen purity; CO_2 in flue gas, etc.

Write for Descriptive Literature

DAVIS INSTRUMENTS

A Division of Davis Emergency Equipment Co., Inc.

80A Halleck St., Newark 4, N. J.

CIRCLE 136 ON READER-SERVICE CARD

The new LFE SM-2 converts digital computer language into a visual message . . . displays alpha-numeric characters, arbitrary or abstract symbols, schematic or logical drawings, graphs, charts and maps.

Twenty-one inch, flicker-free, display tube clearly displays up to 13,000 character messages, or 90 characters per square inch . . . is easily readable with ordinary office lighting . . . features self-contained storage. Brightness and storage are completely independent of the number of characters on any given page.

SM-2 is readily adaptable to data storage and retrieval systems as the on line output device. Typical of this application is LFE's commercially available RASTAD system.

Other applications include air traffic control, intelligence systems, inventory control, production control, process control monitoring, and other applications where information retrieval and display must be simultaneous. Additional specifications available by writing to Dept. 7I.

LFE

COMPUTER PRODUCTS DIVISION

LABORATORY FOR ELECTRONICS, INC.

1079 COMMONWEALTH AVE. • BOSTON 15, MASSACHUSETTS

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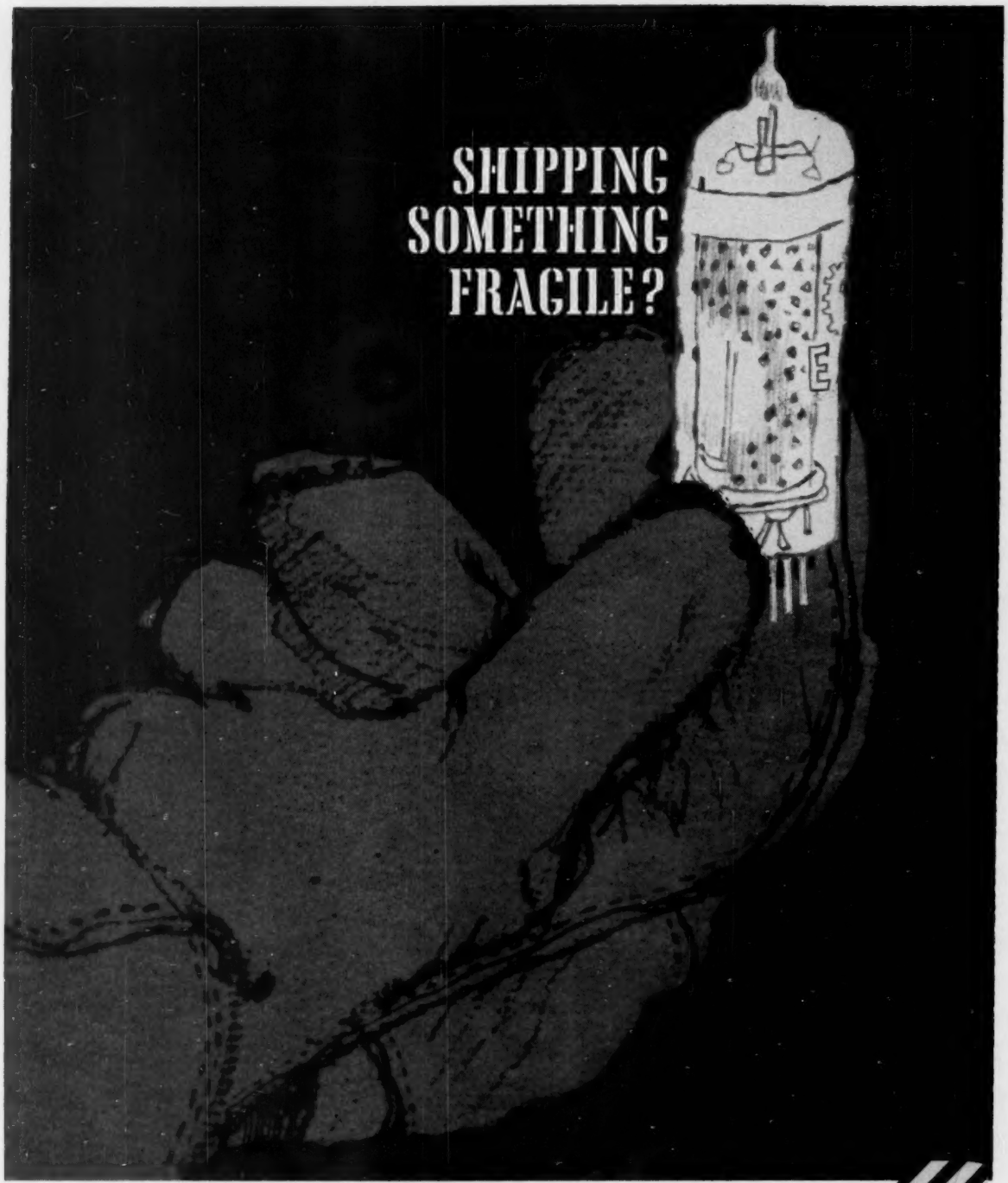


CALL THE GENTLE MEN OF AIR CARGO *Tender treatment of delicate shipments is a KLM specialty. KLM has been flying cargo internationally longer than any other airline... over 42 years, in fact. And all the years of service have taught KLM people the best ways to deliver cargo in a hurry, at low cost... intact. Call your KLM Cargo Representative. He'll send your order to any overseas city. He'll make all the necessary decisions, accept complete responsibility, keep close watch over your shipment till it's delivered. He's the answer man of cargo— the biggest reason why KLM is cargo choice of the world. KLM Royal Dutch Airlines, 609 Fifth Ave., New York, N. Y.*

THE WORLD OVER
KLM
ROYAL DUTCH AIRLINES

CIRCLE 65 ON READER-SERVICE CARD

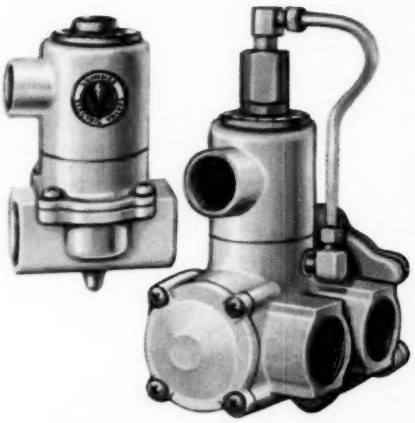
CIRCLE 66 ON READER-SERVICE CARD→

SKINNER EXPLOSION-PROOF SOLENOID VALVES

Skinner has a complete range of Explosion-Proof Solenoid Valves

If you have a control problem involving valves operating in hazardous locations—Class I Group D (gasoline vapors, etc.), Class II Group F (coal and coke dust) and Group G (grain dust)—you can select from Skinner's complete line of two- and three-way explosion-proof standard and high pressure solenoid valves.

- **U.L. approved**
- **A wide range of pressure ratings and orifice sizes**
- **Bodies and coil housings machined to close tolerances—clearance is 0.0005**
- **Stainless steel or naval brass bodies**
- **Stainless steel internal parts**
- **Stainless steel and brass internal parts**



STAINLESS STEEL TWO- AND THREE-WAY SOLENOID VALVES—X5 SERIES

The highest quality and most versatile valves manufactured. So flexible that basic valve can be modified to provide porting, mounting, or flow-control, to meet most applications.

Two-way solenoid valves are available normally closed, normally open and dual purpose. Orifice sizes from 1/32" to 3/8", maximum operating pressure differential 3000 PSI depending on orifice size—NPT pipe size 1/8", 1/4" and 3/8".

Three-way available normally closed, normally open, directional control and multi-purpose. Orifice sizes from 3/64" to 1/4", maximum operating pressure differential 200 PSI depending on orifice size.

TWO-WAY PISTON TYPE SOLENOID VALVES—XR SERIES

These valves, with forged naval brass body and stainless steel piston, handle high flow and high pressure requirements of industrial and commercial applications with most common media.

XR series valves are available with 1/4" orifice and 1/4" NPTF in normally closed or normally open construction. Operating pressure differential 5 to 1250 PSI for AC operation and 5 to 1000 PSI for DC operation.

TWO- AND THREE-WAY HIGH FLOW SOLENOID VALVES—XL SERIES

These diaphragm type solenoid valves meet the high flow requirements of a great many commercial and industrial applications. The unique Skinner diaphragm construction makes possible the exceptionally long service life of this series valves.

Two-way XL series valves are available normally closed and normally open. Orifice sizes are 1/2", 3/4" and 1" with corresponding NPTF pipe connections. The 1/2" orifice model is also available with 3/8" NPTF. Operating pressure differential is 5 to 150 PSI.

Three-way XL series valves are available normally closed, normally open and directional control. Orifice sizes are 3/8", 1/2" and 3/4" with corresponding NPTF pipe connections. Operating pressure differential is 5 to 150 PSI for the 1/2" and 3/4" size and 10 to 150 PSI for the 3/8" size.

TWO- AND THREE-WAY HIGH PRESSURE HYDRAULIC SOLENOID VALVES—X10 SERIES

These stainless steel, direct acting, slide-type valves are precision engineered to control hydraulic systems at pressures up to 2000 PSI.

These high pressure hydraulic valves have a 3/32" inlet and cylinder orifices with 1/8" NPT. They can be used as two-way normally closed or two-way

normally open valves by plugging the appropriate port, and three-way normally closed, or three-way normally open, or dual purpose valves.

• • •

For complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

When you specify solenoid valves, specify Skinner. Skinner solenoid valves are distributed nationally.

THE CREST OF QUALITY

SKINNER ELECTRIC VALVES

SKINNER ELECTRIC VALVE DIVISION
SKINNER PRECISION INDUSTRIES, INC. • NEW BRITAIN, CONNECTICUT, U.S.A.

PRINTED IN U.S.A.

Spray on Statnul

wipe off static...
wipe out error!

False readings in test and panel instruments can easily be caused by static electricity . . . especially when meter faces are made of plastic. Now you can protect for months against static error — actually restore original accuracy — with new Weston STATNUL® anti-static solution!

It's easy to use: Simply spray or apply with saturated cloth — then wipe. STATNUL leaves an invisible conductive shield which drains away static.

Cleans and polishes with every application . . . wards off abrasive air-borne dust and dirt . . . prevents scratching.

Keep a bottle handy to protect your equipment. Each 3½-oz. container can be used hundreds of times.

Mail coupon today or see your local Weston distributor.

WESTON
Statnul

a product of
DAYSTROM, INCORPORATED
Weston Instruments Division, Newark 12, N. J.

← CIRCLE 66 ON READER-SERVICE CARD

Daystrom, Incorporated
Weston Instruments Div., Dept. IC5
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Please send . . . . . bottles of Weston STATNUL ($3.95 each).
Check or money order enclosed ☐ Bill me. Purchase order enclosed ☐

Name . . . . . .

Firm . . . . . .

Address . . . . . .

City . . . . . Zone . . . . . State . . . . . .

CIRCLE 67 ON READER-SERVICE CARD

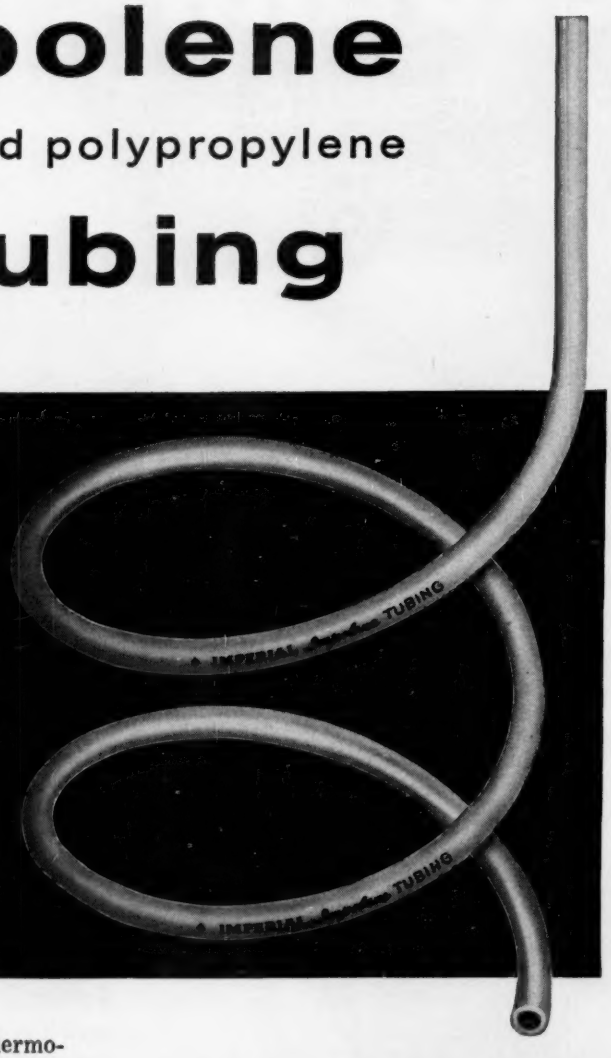
new

Impolene

stabilized polypropylene

tubing

- 30 to 50 times the life of nylon at high temperatures
- 30% lower cost than nylon
- 2 to 3 times the tensile strength of polyethylene
- withstands 3 to 4 times the working pressure of polyethylene



The introduction of Impolene thermoplastic tubing foretells major improvements in the transmission of air and fluids. This Imperial-Eastman stabilized polypropylene tubing now has many proved uses. Many more await it. What's yours? For complete data, write for Impolene Bulletin No. 301.

IMPOLENE

IMPERIAL EASTMAN

Imperial-Eastman Corporation General Offices: 6300 West Howard Street, Chicago 48, Illinois

In Canada: Imperial-Eastman Corporation (Canada) Ltd., P.O. Box 645, Barrie, Ontario

CIRCLE 68 ON READER-SERVICE CARD

new Impolene

with *new* advantages, many *new* uses

High tensile strength. Highest strength-to-weight ratio of all thermoplastic tubing. Working pressures compare favorably with nylon—are 3 to 4 times greater than polyethylene.

Excellent corrosion-resistance. Resists concentrated hydrochloric acid up to the boiling point. Withstands saline solutions at temperatures over 212° F. Shows no detrimental effects in boiling sulfuric acid.

Wide temperature range. Can be used up to 300° F. Has 30 to 50 times the life of nylon at elevated temperatures. Remains flexible at −100° F.

Good abrasion-resistance. High surface hardness gives it much better abrasion-resistance than most thermoplastics.

Odorless . . . tasteless . . . resists sunlight. Approved by the FDA and NSF for food and drinking water applications.

Use Impolene tubing for air lines, control panels, instrumentation and lubrication systems, processing and construction machinery—many other uses.

Available in 500′ to 1000′ spools in O.D. from ⅛″ to ⅜″. Other sizes available on special order.

Poly-Flo Fittings—designed for use with all plastic tubing, yet usable with soft metal tubing. Withstand pressures beyond burst strength of tubing. Available in a complete range of sizes and styles.

Now Imperial-Eastman meets all your requirements for hydraulic-pneumatic-flow system components: tube fittings, valves, couplings, flexible and rigid hydraulic and pneumatic lines, thermoplastic tubing, tubing tools.

TUBING

IMPERIAL — EASTMAN

CIRCLE 68 ON READER-SERVICE CARD

IGS PANHANDLE PETE

WESCO! installs new data processing system

WESCO! has installed a completely automatic YBM-EDP system. All WESCO! sales receipts, warehousing, inventory, payroll, trends, bookkeeping and scientific problems can be performed rapidly and automatically by this stored-program solid-state YBM-EDP machine, the most advanced machine of its type.

To report exactly how it performs, we have sent our genial sales manager, Waldo Klappsadle, to out data-processing and accounting department to report to our readers how this system is working. Here comes Waldo now.

"Waldo, how is the new YBM-EDP system working?"

"Perfectly," answers Waldo. "All our payroll, accounting, inventory, warehousing, bookkeeping, and scientific problems were done between the hours of 9 and 10 AM yesterday."

"Wonderful," I answer, "What is the machine doing now?"

"Nothing," replies Waldo.

"Nothing," I shriek, "at $4650.74 per hour?"

"Nothing," replies Waldo. "We even figured out who was going to win the 1961 world series, but no problems are left."

"Doing nothing at $4650.74 per hour is no laughing matter, Waldo," I points out. "How much bookkeeping would we need to break even on this computer?"

"Two hundred more employees, forty new salesmen, and thirty new R&D men would just about keep that computer busy for 40 hours per week, which is the break-even point," says Waldo.

"Then WESCO! must expand—right away. Put some ads in that fine trade journal *INSTRUMENTS & CONTROL SYSTEMS*, announcing that WESCO! is doubling its force and moving into new and enlarged headquarters, and that we owe it all to our new fabulous YBM-EDP system."

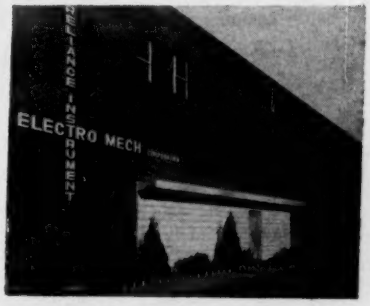
Panhandle Pete

Judging by the Company We Keep...

Electro-Mech Corporation expands to better serve the increasing "Company We Keep." We now have representatives in the major industrial areas of the United States. From Coast to Coast we stand ready to solve your control system problems.

"MEANWHILE BACK AT THE HOME OFFICE"—we also have expanded.

Pictured below is our new modern, 24,000 square feet, plant at 500 Livingston Street, Norwood, New Jersey.



Within—the most modern production, engineering, and test facilities are producing control systems and control centers of the highest quality. No detail is overlooked in providing the most thoroughly-engineered and tested control systems.

Regardless of your location, Electro-Mech Corporation is at your call. Allow us to "modernize" your instrumentation. Consult Electro-Mech on all your future control systems.

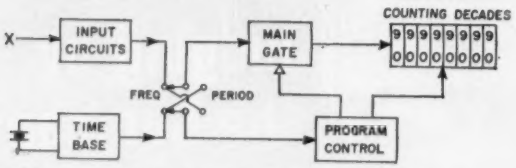
Electro-Mech Corp., Norwood, N. J.

Electro-Mech

CIRCLE 63 ON READER-SERVICE CARD

ICS BRIEFS

1000-Megacycle Standard



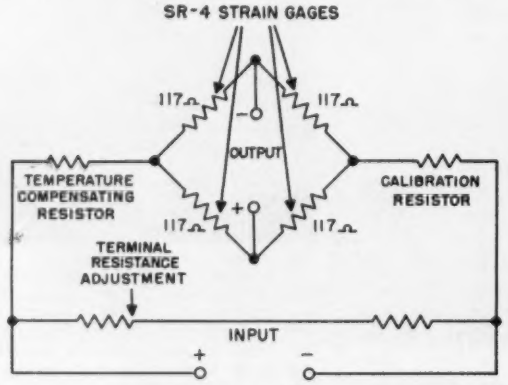
Frequency and Period Measurement Diagram

New 1000-Mc Frequency Standard features stability of 5 parts in 10^{10} per day (averaged over 10 days after 60 days operation). Delivers high performance at reasonable cost with 5-Mc fifth-overtone Warner crystal and 2-stage oven. Low noise; Synchronometer gives ±0.2 msec for time comparisons; direct digital readout; 10-kc and 100-kc squares waves . . . (*From 4-page Form 3051-A, General Radio Company, West Concord, Mass.*)

FOR THIS LITERATURE CIRCLE 206 ON READER-SERVICE CARD

Strain-Gage Sensing Elements

SR-4 strain gage-actuated sensing elements (Manufactured by Baldwin-Lima-Hamilton Corp., Waltham, Mass.) can be used with Foxboro instruments, such as



STANDARD LOAD CELL CIRCUIT

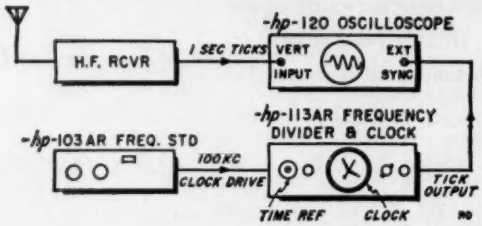
the Resistance Dynalog Recorder and the Null Balance Portable Indicator . . . for measurements of load (weight) and cantilever type forces . . .

The basic construction of a load cell consists of a high-strength rectangular steel column to which four strain gages are bonded. These four gages are electrically connected in the form of a Wheatstone Bridge, initially balanced, as shown. Temperature compensating resistors are included in the circuit to maintain the accuracy of the bridge over a wide range of temperatures . . . (*From 6-page Bulletin 27-25b, Foxboro Co., Foxboro, Mass.*)

FOR THIS LITERATURE CIRCLE 207 ON READER-SERVICE CARD

Time Comparison

Time comparisons with broadcast standard time signals may be made as shown. The only equipment required in addition to the 113AR, 103AR, and 724AR

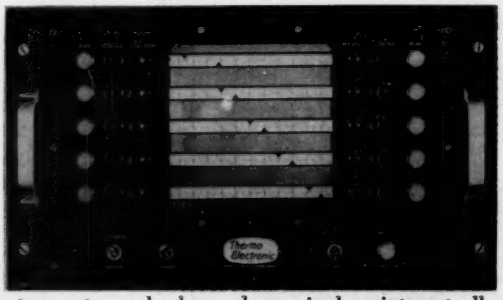


is a triggered oscilloscope such as the 120AR and a receiver. Transmissions from WWV (or any other station transmitting precise time signals) are received and their "time ticks" are connected to the vertical input of the oscilloscope . . . By successive adjustment of the 113 AR Time Reference control and the oscilloscope sweep speed, a reference condition is established in which the time between the two ticks is very short and is accurately known. As the oscillator under test drifts with respect to the received time signals, the Time Reference control may be adjusted to re-establish the reference condition between the two ticks. The amount by which the Time Reference control must be adjusted indicates the time drift of the oscillator under test . . . (*From 3-page bulletin, "Model 103AR Quartz Oscillator," Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif.*)

FOR THIS LITERATURE CIRCLE 208 ON READER-SERVICE CARD

Multi-Point Controller

The new Thermo Electronic Multi-Point Temperature Controller provides accurate automatic two-position control for up to ten separate processes . . . The



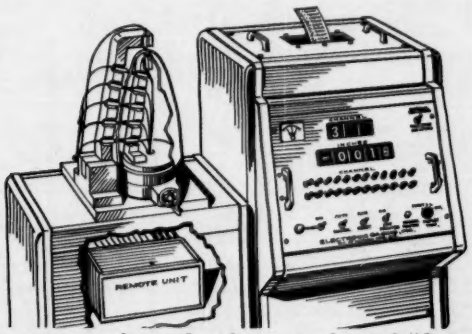
instrument can also be used as a single point controller, a five-point three-position controller and a manual-balance indicator. Any points not being used for control of a multiple-temperature process can monitor other processes.

In operation, input signals are scanned in sequence, at the rate of 3 seconds per point, and compared to slide-wire control settings. Signal deviations are amplified in accordance with their polarities by the high gain, sensitive Thermo Electronic relay control amplifier. The amplified signals provide corrective action through ten load relays connected to the processes being controlled . . . (*From News Release and Bulletin 52, Thermo Electric Co., Inc., Saddle Brook, N. J.*)

FOR THIS LITERATURE CIRCLE 209 ON READER-SERVICE CARD

Electronic Gage

The Winslow Universal Electronic Gage automatically reads up to 24 gage positions and prints the results in as little as one minute . . . This multi-purpose

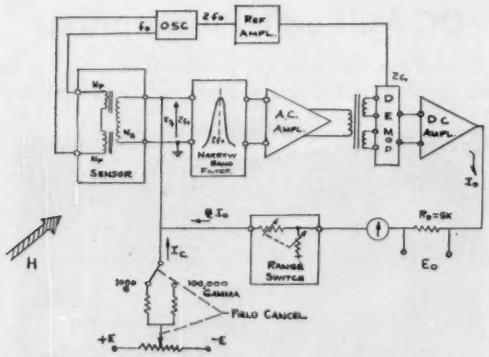


instrument can be used with any mechanical "design" gage of the type using standard dial indicators or air gage probes. And it can be moved from one design gage to another with no alteration except set-up . . . Checks external and internal gage points on the part. Checks thickness between any two opposed Gaging Cartridges . . . Prints the channel number (gage position) and the variation to the nearest .0001" . . . (*From 4-page bulletin, Electronic Gaging, Inc., Div. Winslow Manufacturing Co.,* 1751 *E.* 23 *St., Cleveland* 14, *Ohio*).

FOR THIS LITERATURE CIRCLE 210 ON READER-SERVICE CARD

Magnetometer

The Honeywell Magnetometer is a precision instrument which measures the earth's magnetic field . . . With a twist of a knob mounted on the control panel,



the magnetometer is converted to a permeable-object director . . .

When an external field, H, is present, the output of the sensor is a voltage containing the second harmonic of f_o. The excitation voltage for N_p and N_{p1} is obtained from the oscillator which receives B voltage from two mercury cell batteries. The amplitudes of this second harmonic is directly proportional to the magnetic field . . . For the magnetometer, the operating principle is the same, except that the quantity measured is a magnetic field rather than a d-c current or voltage . . . (*From 5-page Bulletin BMI-EMI, Minneapolis-Honeywell Regulator Co., Boston Div.,* 40 *Life St., Boston* 35, *Mass.*)

FOR THIS LITERATURE CIRCLE 211 ON READER-SERVICE CARD

GET *IMMEDIATE* ANSWERS WITH

YOUR OWN *Dillon* TESTING DEPARTMENT!

PROFESSIONAL Testing Equipment Within Reach of the Average Shop Budget!

Your own *available* test department can be worth its weight in gold. In addition to getting *immediate* answers to your problems, you'll save outside fees...and costly employee waiting time.

Whatever your product, there's a Dillon instrument you can use to advantage. Tensile, compression, torque or shear . . . 1 pound to *1 million* pounds! Anyone can operate. Rugged and dependable. Guaranteed accuracy!

VALUABLE FREE ENGINEERING BROCHURES

If you're just starting or adding to your testing department, you'll need this data on prices, and capacities...plus 100's of new testing ideas! Write today . . . specify brochures wanted!

Dynamometers ☐ Testers ☐ Load Cells ☐

128

TO MEASURE, WEIGH, TEST OR CONTROL – CALL ON DILLON ...PRECISION INSTRUMENTS FOR 3 DECADES!

W. C. *Dillon* & COMPANY, INC.

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CIRCLE 70 ON READER-SERVICE CARD

PHILADELPHIA
THERMAL CONTROLS AND
THERMOMETERS
Specify!
THE BEST!
A half century of experience is back of every instrument we make. You get assured accuracy and long dependable performance when you specify "Philadelphia." Our specialized staff will be glad to discuss your problem in our field.
SEND FOR CATALOG
110
Since 1905
PHILADELPHIA THERMOMETER CO.
4401 N. Sixth St. • Philadelphia 40, Pa.

CIRCLE 71 ON READER-SERVICE CARD

Approximately 1/3 Actual Size

INSCO

STEP-FUNCTION SPEED REDUCTOR

AN INSTRUMENT TRANSMISSION FOR PRECISE MULTIPLE SELECTION OF SHAFT SPEEDS

Versatility of ten ratios . . . to 1000:1! Desired shaft speed can be quickly selected at the turn of a dial, without stopping the input shaft. Geared design provides exact repeatability and non-slip drive . . . ideal for new instrument design, breadboards, general laboratory applications.

OIL BATH LUBRICATION . . . SPEEDS UP TO 3000 R.P.M. . . . TORQUE TO 50 OZ.-IN. . . . VARIETY OF MOUNTING ARRANGEMENTS.

CHART DRIVES • SPEED REDUCTORS • INSTRUMENT DRIVE SYSTEMS

INSCO COMPANY

DIVISION OF BARRY WRIGHT CORP.

GROTON, MASSACHUSETTS

CIRCLE 72 ON READER-SERVICE CARD

Piezoelectric "Spark Pump"

The piezoelectric effect is useful because it offers a means for direct conversion of mechanical energy to electrical energy, and vice versa. In addition to these

GENERATOR APPLICATION

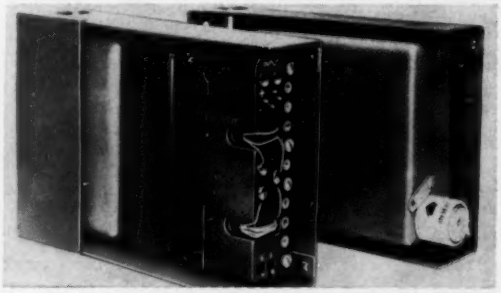
	Energy Conversion %	Dielectric Constant	Young's Modulus million p.s.i.	Voltage per unit stress
Rochelle Salt	80	350	3	90
ADP	10	15	3	180
Barium titanate	15–25	500–2000	17	10–15
Lead titanate zirconate*	25	600	12.5	24
PZT**—range	35–50	350–2500	8.5–14	20–40
PZT-4**	42	1300	12	24
PZT-5**	45	1600	9	24
Lead niobate	18	250	5	40
Quartz	1	4	12	58
Desirable:	High	Depends on load impedance	Low	High

"generator" and "motor" functions, it is used to provide wavelength selection in electronic circuits . . . The Spark Pump, recently introduced by Clevite as an ignition source for gasoline engines, is an example of the potential of the new technology. Two small elements made from a special formulation of lead zirconate-lead titanate are the heart of the device. The formulation is balanced to enhance electrical generating properties. When mechanical pressure is applied through a lever system, the elements produce 20,000 volts . . . Ignition is consolidated in one bolt-on package, and servicing is simplified . . . (*From* 16-*page illustrated booklet, Clevite Electronic Components, Bedford, Ohio.*)

FOR THIS LITERATURE CIRCLE 212 ON READER-SERVICE CARD

DC-Millivolt Preamplifier

Type PA-5 DC-millivolt Preamplifier unit for use with thermocouples, strain gages and resistance bulb



elements is made up of four encapsulated modules: Input Module, AC Amplifier, Demodulator-Modulator, and Power Supply. Input: span 5 mv minimum, 50 mv maximum; suppression ±50 mv, but less than three times span. Limitation may be waived where ambient temperature is constant. Range adjustment: Inductive calibration provides for continuous adjustment over entire range. Outputs available: d-c current, d-c voltage, square wave ac. Terminal linearity: better than 0.2% . . . (*From News Release and bulletins, De Var Systems, Inc., 494 Glenbrook Rd., Glenbrook, Conn.*)

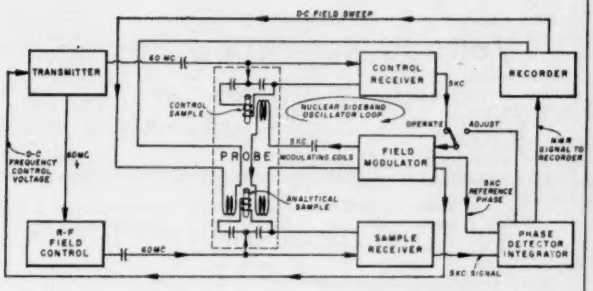
FOR THIS LITERATURE CIRCLE 213 ON READER-SERVICE CARD

Analytical NMR Spectrometer System

The A-60 Analytical Spectrometer System is a High Resolution Nuclear Magnetic Resonance instrument which provides information about organic molecules through its sensitivity to the resonance signals of the hydrogen nucleus. The inclusion of an integrator in this system makes available both qualitative and quantitative information about an organic molecule. Through the use of either of these parameters NMR can uniquely reveal a vast amount of information important to the organic chemist . . .

The instrumentation which is needed to observe Nuclear Magnetic Resonance is: (1) a radio-frequency transmitter-receiver, (2) a magnet capable of producing a highly uniform and stable magnetic field, (3) a suitable means of sweeping that magnetic field, (4) a graphic recorder driven in synchronism with sweep of the field.

The figure illustrates the block diagram of the A-60 Analytical Spectrometer System . . .



In the Nuclear Sideband Oscillator, a modulation frequency of approximately 5 kc is applied to the modulating coils in the sample probe. This modulation . . . appears at the control receiver as a 60 mc carrier signal and two sideband signals at 60 mc plus and minus the 5 kc modulation frequency. At the control receiver the 60 mc carrier is demodulated and only the 5 kc sideband signals remain. The upper sideband signal is selected, and applied to the input of the field modulator. The field modulator amplifies this audio voltage and again applies it to the modulating coils which completes the Nuclear Sideband Oscillator loop . . .

With the Nuclear Sideband Oscillator loop in operation, there remains the matter of obtaining spectra from the analytical sample. The control sample and analytical sample are located adjacent to each other and are excited by the *same* RF and modulation fields. By sweeping the current in a coil surrounding the analytical sample, in synchronization with the horizontal scan of the recorder, the field at the sample may be swept and the resulting spectra recorded in a reproducible and precisely calibrated fashion . . . (*From 16-page brochure, Varian Associates, Instrument Div., Palo Alto, Calif.*)

FOR THIS LITERATURE CIRCLE 214 ON READER-SERVICE CARD

Select from over 3,500 different SOLENOID VALVES from VALCOR

Series SV-54 (3 way-4 way) general purpose solenoid valves for air, oil and water. Rugged construction, yet inexpensive. Multi-million cycle life. Pressure ratings up to 150 psi. Nylon seat outlasts steel. Infinite varieties available . . . lists as low as $10.75.

Series SV-61 (2 way) Nylon body valve is ideal for general purpose and OEM installations where millions of operating cycles are vital. Nylon seat and port threads outlast steel, yet cost less. Non-corrosive, shock-resistant, proof-pressure.

Series SV-5100 Specifically designed to handle the most corrosive media in industry. Manufactured in Teflon, PVC and Nylon varieties. Diaphragm construction prevents media contact with any metal. Available in direct-acting or piloted models.

VALCOR SOLENOID VALVES

FREE...new 16 page brochure—lists over 500 corrosive media—coded for correct valve selection.

For complete information on these or other models, write or call:

VALCOR ENGINEERING CORP.
5366 Carnegie Ave., Kenilworth, N. J.
CHestnut 5-1665

CIRCLE 73 ON READER-SERVICE CARD

CUT COSTLY INSTRUMENT MAINTENANCE

with

Clean Dry Oil-Free Compressed Air

An Adams aftercooler and cyclone separator installed in your instrument air supply cools the discharge air to within 2° of cooling water temperature. Over 90% of the moisture and virtually all of the oil are condensed. The exclusive Adams cyclone separator then removes the condensed liquid oil and water and other foreign material with uniform high efficiency — over the entire operating range. This air is entirely suitable for air motor and most control applications. When bone dry air is needed, the chemical drier load is then limited only to polishing action, since the bulk of the moisture will have been removed by lower cost condensation. Why not review the cost cutting advantages of an Adams aftercooler-separator combination? Ask today for your free copy of Bulletin 714. R. P. Adams Co., Inc., 265 East Park Drive, Buffalo 17, New York.

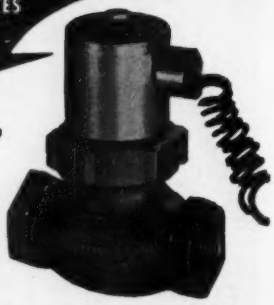
ADAMS QUALITY COMES THROUGH

CIRCLE 74 ON READER-SERVICE CARD

Check these prices on Gould Type M

Solenoid Valves

TYPICAL USER NET PRICES
F. O. B. FACTORY



SIZE	1 to 5	100 to 499
½"	$15.40	$11.15
¾"	18.50	13.60
1"	24.25	18.50
1½"	48.00	42.40

2-Way • General Service
Packless • Normally Closed

Sizes ⅜" to 3" • Temperatures to 250° • Pressures to 400 psi • Molded epoxy resin water-proof coils • Unbreakable piston rings • No damaging hammer • Easy-off "O" ring bonnet construction in sizes ⅜" thru ¾" • High temp coils and explosion proof housings available. Immediate delivery. Ask for Bulletin 600-M.

SOME OTHER TYPES OF GOULD SOLENOID VALVES

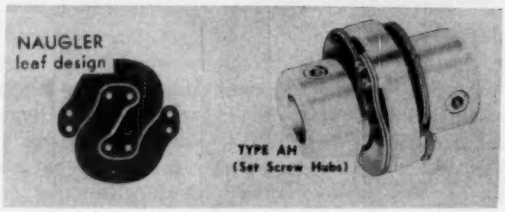
D—Adjustable flow control, adjustable cushioning control to reduce shock, manual opening. **HV**—Four independent controls—opening, closing, flow, manual opening. **G**—Stainless, fractional ports, pressures to 1,000 psi. **GX**—All 316 stainless, fractional ports. **K**—Stainless, ½" to 2". **MDW**—Direct acting. NOTE: Special assemblies for exacting requirements.

J. D. GOULD CO. · 4707 MASSACHUSETTS AVE. · INDIANAPOLIS 18, IND.

GOULD SOLENOID VALVES — VELVETROL

CIRCLE 75 ON READER-SERVICE CARD

Miniature Flexible Couplings

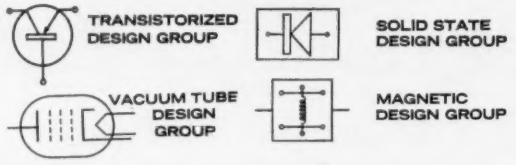


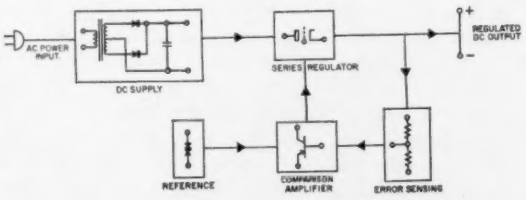
The Naugler Flexible Coupling is unique because of its leaf design, which allows true flexing to compensate for angular, lateral and axial misalignment with minimum resultant bearing pressures . . . It is compact and lightweight (aluminum hubs and center members) yet provides high torque capacity through the hardened beryllium copper leaves. Static and dynamic balance make it ideal for high speed applications. There are no moving or sliding fits between the members (zero backlash) and the all metal construction requires no lubrication. Size range of ½" to 1½" O.D. or Series; models available with set screw (shown) or clamp type hubs . . . (*From* 4-*page Catalog* 40, *Naugler Engineering, Inc.*, 19 *Madison Ave., Beverly, Mass.*)

FOR THIS LITERATURE CIRCLE 215 ON READER-SERVICE CARD

Voltage Regulated Power Supplies

Kepco's index to Voltage Regulated Power Supplies includes four design groups:





Over the past decade semiconductor technology and Kepco engineering have produced a series of quiet revolutions which have radically transformed the physical and electrical characteristics of Voltage Regulated Power Supplies . . . The transistorized HB Group features:

STABILITY: For 0.1% Models: Less than 0.1% or 10 mv, whichever is greater, over a period of 8 hours, at constant ambient temperature. For 0.01% Models: Less than 0.01% or 2 mv, whichever is greater, over a period of 8 hours, at constant ambient temperature.

RIPPLE: Less than 1 millivolt rms . . . (*From* 32-*page Catalog B*-611, *"DC Power Supplies," including specs, diagrams, and nomograph of voltage drop across load supply leads, Kepco, Inc.*, 131-38 *Sanford Ave., Flushing* 52, *N. Y.*)

FOR THIS LITERATURE CIRCLE 216 ON READER-SERVICE CARD

TEMPAK metallic sheathed ceramic insulated thermocouple material

Now, at last, Temptron has introduced TEMPAK metallic sheathed ceramic insulated wire and thermocouple material. This is the product everyone with temperature sensing problems has been waiting for. It embodies the finest materials available and is a quality product manufactured by the highly skilled people of TEMPTRON, INC.

During the past several years, there has been an increasingly greater demand for functional reliability, long life and high accuracy. One of the first steps taken by TEMPTRON towards this end was a comprehensive quality and operational life study of sheathed thermocouple components and the processes and facilities used to produce them.

It soon became apparent that many of the various brands of this material on the market could not provide the required optimum accuracy and trouble-free long life. From this evaluation, new technical and manufacturing concepts emerged; that sheathed thermocouples were an important part of the total recording or control system; that thermocouples would have to be engineered with predetermined physical and electrical characteristics in mind, just as any other high quality components; that special manufacturing equipment and environmental controls of advanced design were required. Today, mineral oxide insulated sheathed thermocouples to precise critical characteristics are custom designed and produced for the special applications involved.

The characteristics of TEMPAK precision ceramic insulated thermocouple material make it ideal for a wide variety of applications. TEMPAK has found its way into just about every industry. It is used in chemical processing under conditions of extreme pressure. In power generating and oil refineries it is used to measure furnace tube wall temperatures in extremely corrosive atmospheres. It is not affected by conditions of extreme vibration, moisture and shock. Due to its flexibility and available long lengths, TEMPAK now gains access to places formerly restricted to the conventional type thermocouple. TEMPAK is used to measure temperature of the coolant in the cores of nuclear reactors as well as in the aircraft and missile fields.

From the day of its introduction into the heat sensing field TEMPAK has become the uncontested leader. Its high quality and long life eliminate costly shutdowns, afford maximum apparatus protection and permit uninterrupted maintenance of process schedules.

If you are buying thermocouples for accurate long life—you want TEMPAK.

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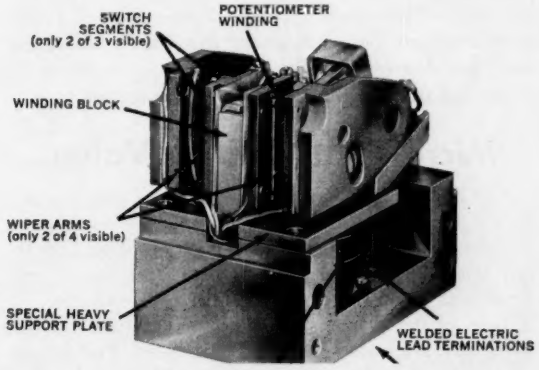
Pressure Transducer

The TP-200 is a potentiometric-type transducer that uses a versatile, variable temperature-compensated mechanical amplification system to combine the high output signal and extreme accuracy characteristics of potentiometer output elements with the reliability, ruggedness, accuracy and excellent responsiveness of a capsular Ni-Span-C diaphragm . . . Pressure causes the capsule to deflect, actuating the potentiometer and switch wiper arms through a simple, dynamically-balanced pivot and lever mechanism . . . (*From 4-page bulletin, Fairchild Controls Corp., 225 Park Ave., Hicksville, L. I., N. Y.*)


SWITCH SEGMENTS (only 2 of 3 visible)
POTENTIOMETER WINDING
WINDING BLOCK
WIPER ARMS (only 2 of 4 visible)
SPECIAL HEAVY SUPPORT PLATE
WELDED ELECTRIC LEAD TERMINATIONS

FOR THIS LITERATURE CIRCLE 218 ON READER-SERVICE CARD

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PANDUX® RECORDING THERMOMETER

Highly portable field service unit records **temperature and time** on a replaceable paper chart, in permanent or temporary installations, **in any position.** May be packed with shipments or encased in polyethylene bag for humid or corrosive atmospheres. No ink to spill, run or freeze. May be sealed to prevent tampering. Only 3-15/16" dia. by 2-7/8", wt. 14 oz.

5 RANGES
0° F. to 100°F.
20° F. to 220° F.
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Minus 40° F. to 160° F.
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24 HOUR or 7 DAY
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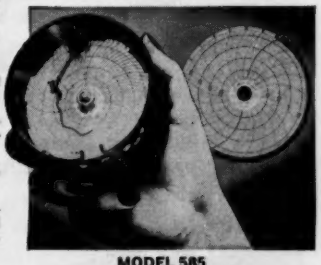

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*Also Centigrade equivalents.

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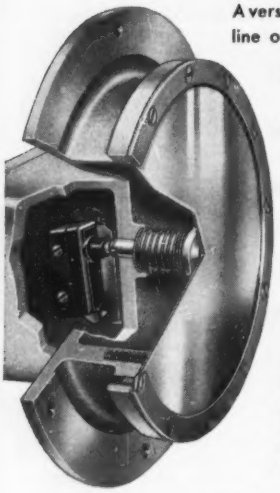
Dealer Inquiries Invited . . . Some Territories Still Open.

CIRCLE 113 ON READER-SERVICE CARD

NEW
AUTO-BIN-DICATOR*
AUTOMATIC BIN LEVEL INDICATOR



A versatile addition to the Bin-Dicator line of bulk material level controls.

NEW corrosion-resistant construction

NEW stainless steel diaphragm

NEW super-sensitive operation

Explosion-proof and general purpose models listed by Underwriters' Laboratories, Inc.

Prevents overflowing of bins, clogging of conveyors, choking of elevators, damage to machinery; cuts operating costs. Provides simple, reliable, positive control at low cost.

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WEIGH
ELECTRONICALLY
Ametron® CRANE SCALES

Designed for fast —easy Installation Visual or Printed Weights

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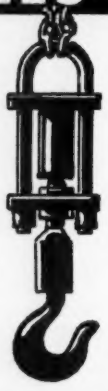

Recorder may be mounted in crane cab or in other convenient locations. Prints tape or cards. Available at low costs in 5, 10 and 15 capacities. Rugged construction decreases maintenance.

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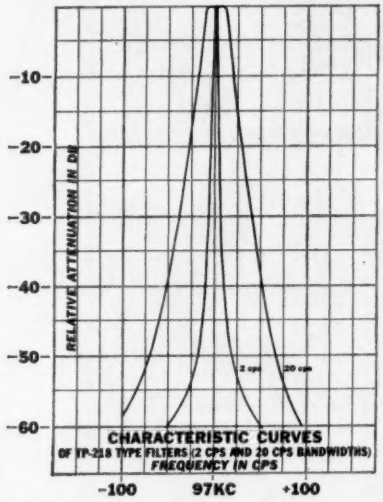
Wave Analyzer

The TP-625 Analyzer System is of the heterodyne type and requires as the minimum system, an Oscillator, an Analyzer and one or more filters. All filtering



is at the frequency of 97,000 cycles per second. An extremely stable, variable-frequency type, with its own regulated power supply, the TP-626 Oscillator scans three bands—0-250 cps, 0-2500 cps, 0-25,000 cps . . . The constant bandwidth selectivity of the Wave Analyzer System is dependent upon the TP-627 Analyzer . . . A maximum of four filters may be mounted within each Analyzer or, if desired, an external filter panel can be provided for a greater number of filters to be used, further increasing flexibility . . . TY-218 Type Filters provide the high degree of accuracy afforded by the TP-625 Wave Analyzer System. High rejection, steep sides and flat top (within 1 DB) are some of the response characteristics that are provided in standard bandwidths of 1, 2, 5, 10, 20, 50, 100 and 200 cps . . . (*From 6-page bulletin, Technical Products Co., Instrument Div., 6670 Lexington Ave., Los Angeles 38, Calif.*)

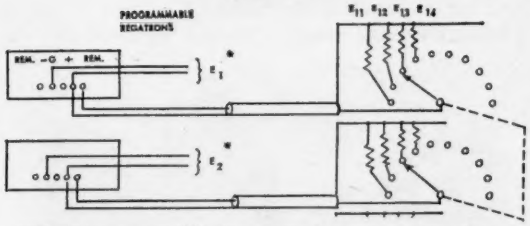
FOR THIS LITERATURE CIRCLE 219 ON READER-SERVICE CARD

Micro-Cam Control Valve

The Hauck Micro-Cam Valve provides positive, accurate, uniformly graduated control, removing the uncertainty and guesswork from regulation of oil flow to any type of burner, thereby making operation of oil-fired heat processing equipment more dependable . . . A turn of the handle from open to absolute shut-off gives any graduated capacity in between. The degree of opening is governed by a cam with a knife edge which rotates against a V-slot in a flat plane and working with very little bearing pressure . . . The cam's knife edge easily cuts away any grit, dirt or carbon that may pass into the valve . . . Because it produces straight line discharge, once the flow in gallons has been established, the valve serves as a practical metering device . . . (*From 4-page Bulletin DA-2, Hauck Manufacturing Co., 124-136 Tenth St., Brooklyn 15, N. Y.*)

FOR THIS LITERATURE CIRCLE 220 ON READER-SERVICE CARD

Programmable Power Supplies

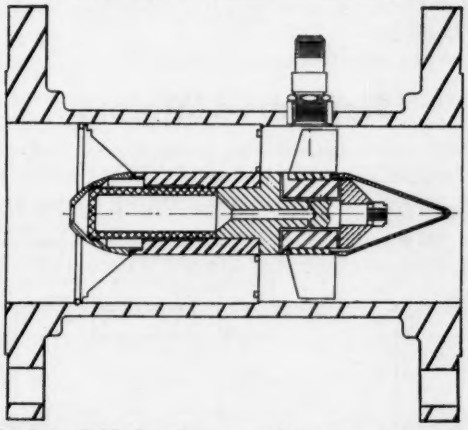


The Programmable Regatron is a new type of power supply designed to meet the need for remote control arising out of the increasing tendency towards automation, centralized control, etc. The word "programmable" has been coined to describe the ability of the unit to be controlled, or programmed from a remote or central point . . . The voltage controls for all of the power supplies in a test console can be brought to a central operating point, thus facilitating manipulation by the operator . . . (*From 4-page Technical Note 21B, Electronic Measurements Co., Inc., Eatontown, N. J.*)

FOR THIS LITERATURE CIRCLE 221 ON READER-SERVICE CARD

Turbine Flow Sensors

Series FF Flow Sensors measure fluid flow by determining fluid velocity in a passage containing a freely spinning turbine wheel. The turbine, which has



eight helical blades, is mounted in the center of the straight through passage. Passage of fluid through the sensor results in rotation of the turbine at a speed proportional to the flow rate, while the total number of revolutions is proportional to the total volume of fluid that has passed through the sensor. As the turbine rotates, an a.c. voltage is induced in a coil containing an Alnico magnet mounted externally to the fluid passage. The passage of each turbine blade past the face of the pickoff coil changes the total flux through the coil, thereby inducing one cycle of a.c. voltage. The frequency of the pulses thus generated is a measure of the flow rate, while the total number of pulses measures the total volume . . . (*From 42-page Products Catalog, Waugh Engineering Co., 7842 Burnet Ave., Van Nuys, Calif.*)

FOR THIS LITERATURE CIRCLE 222 ON READER-SERVICE CARD

modernize

PRODUCTION CONTROL *at low cost...*

Standard Instrument production controls provide immediate benefits to manufacturers and users of packaging—from production of package to filling lines.

TALLY COUNT—count and batch high speed production electronically, actuate mechanisms at any pre-set count.

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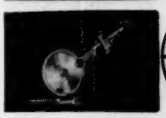
ROBOT-EYE PHOTO-ELECTRIC CONTROL—count, inspect, sort, start and stop machinery photo-electrically.

For complete information on the above and other production controls, write for Brochure IR-5.



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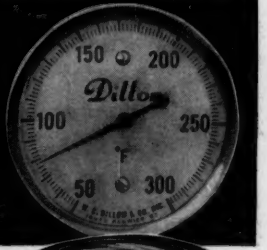
CIRCLE 79 ON READER-SERVICE CARD

Investigate the
Dillon
Stainless Steel
Thermometer



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- 1", 1 1/16", 2 5/16", 3", 5" head sizes
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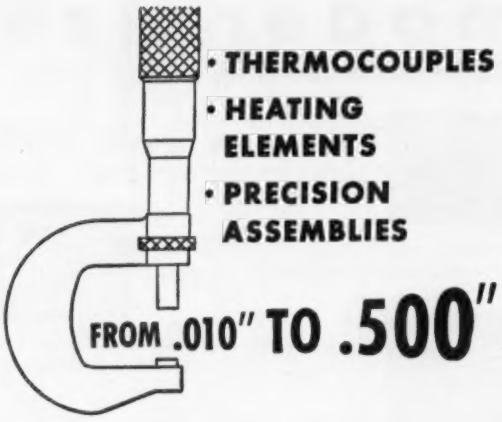
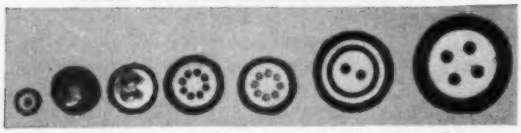
CIRCLE 80 ON READER-SERVICE CARD



WITH CONFIGURATIONS FOR *ALL* YOUR REQUIREMENTS



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Pyro ELECTRIC, INC.
WALKERTON, INDIANA

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New Stock Molded Knobs

AVAILABLE WITH OR WITHOUT SKIRTS

4 Standard Sizes

Meet MIL-P-14 Specs

MODEL RB-1250-SK Illustrated

Molded of thermosetting phenolic or urea materials. Available in 4 standard sizes with nickel plated brass inserts for ¼" or ⅛" diameter shafts. Aluminum decorative inserts or skirts, etched and filled as desired . . . various anodized finishes, plain or radially spun. Write for new catalog illustrating Rogan's complete line of stock molded knobs.

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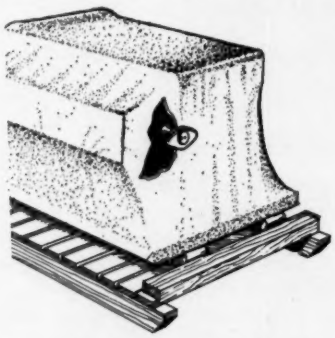
Moisture Content Indicator

The Hydrotector is a versatile simple-to-operate system for determining the moisture content of sealed packages without breaking the seal or destroying the

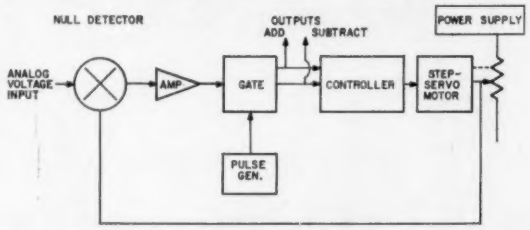


package. The equipment inspects all types of containers including those fabricated of heavy metal or plastic, light metal, plastic cocoon, and flexible-barrier-type materials . . . The Hydrotector consists of two units: (1) sensing element mounting (with sensing element) and (2) a humidity indicator. To operate, an element and its mounting are placed permanently inside the package or area to be monitored (as shown). The operator merely brings into contact the terminals of the indicator cable with the terminals on the sensing element mounting, whereupon the dial pointer indicates the moisture conditions within the package . . . (*From 68-page Catalog 661, Hygrodynamics, Inc., 949 Selim Rd., Silver Spring, Md.*)

FOR THIS LITERATURE CIRCLE 223 ON READER-SERVICE CARD

Step-Servo Motors

ADC pulse-operated Step-Servo Motors and Controllers are new servo components which offer a low cost, reliable solution to many automatic control prob-

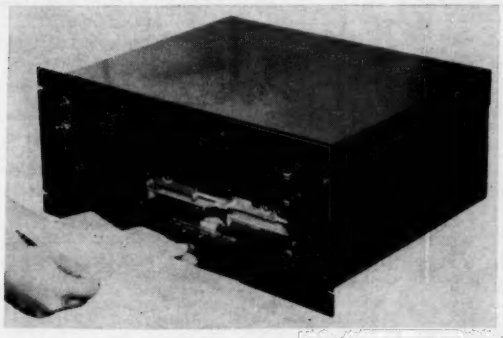


lems. They are used either as digital to analog converters or as analog to digital converters. Pulse data can be converted into shaft rotation with sufficient torque and accuracy to drive and position precisely almost any indicating instrument or transducer . . . The circuit (shown) accurately converts input DC voltages to output pulses. The input voltage is compared to a fraction of the reference voltage; as long as there is an error signal present, pulses will be produced from the gating circuit causing the step-servo motor to step until the amplifier input voltage is driven to a null. The converter output is a non-weighted binary signal . . . (*From 8-page brochure, Automation Development Corp., 11824 W. Jefferson Blvd., Culver City, Calif.*)

FOR THIS LITERATURE CIRCLE 224 ON READER-SERVICE CARD

Programming Devices

Punched Card and Punched Tape Programmers . . . developed to fill the critical need in industry for a multi-channel control (are) capable of operating in-



dependently of complicated coding and decoding, extensive memory systems, and sensitive translation apparatus . . . The Punched Card Programmer (shown) is an electro-mechanical card reader that will control 85 individual load circuits through as many as 30 available functions or steps . . . Circuit completion is accomplished by brush wipe through the punched holes against the exposed contact segments . . .

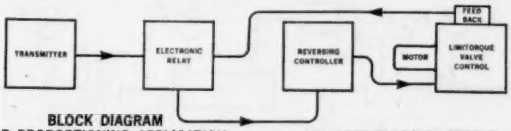
The Punched Tape Programmer is very similar to the Punched Card Programmer but utilizes a 9″ wide tape rather than the 5″ x 9″ vinyl card . . . There are 64 steps to each foot length of tape, thereby providing a quantity of steps limited only by the length of the tape . . . (*From* 4-*page Bulletin* 100*TP*, *Industrial Timer Corp.*, 1407 *McCarter Highway*, *Newark* 4, *N. J.*)

FOR THIS LITERATURE CIRCLE 225 ON READER-SERVICE CARD

Limitorque Valve Control

Limitorque is an actuating device for controlling and limiting operating travel of valves, etc.

Critical control is of prime importance in automatic



BLOCK DIAGRAM FOR PROPORTIONING APPLICATION — ARROWS INDICATE THE SIGNAL DIRECTION

operation because most controlled items (valves) are damaged through improper seating or by meeting a foreign obstruction during travel. By limiting torque and thrust loads with its torque limit switch, Limitorque protects all operating parts from overload. Torque and thrust protection may be varied by means of a micrometer adjustment of the torque limit switch and thereby enabling operating personnel to compensate for change of service conditions . . .

Limitorque minimizes overshoot from the set point of the control instrument with precision cut gearing and controlled braking, thus minimizing any tendency to hunt . . . (*From* 4-*page Bulletin* 6-60 *and* 16-*page Bulletin* 1-60, *Philadelphia Gear Corp.*, *King of Prussia*, *Pa.*)

FOR THIS LITERATURE CIRCLE 226 ON READER-SERVICE CARD

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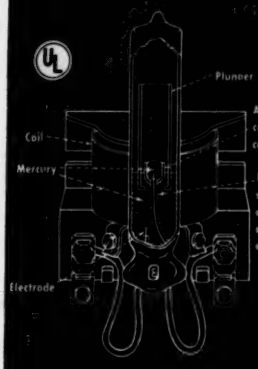
ENGINEER'S FACT FILE

MERCURY PLUNGER RELAYS

From 20 to 100 AMPS



Available in Single Pole, Double Pole or Triple Pole Units

FREE: Practical reference manual. Fully illustrated. Covers all types and uses of Mercury Plunger Relays that provide millions of makes and breaks without maintenance. Constant, uniform action. Hermetically sealed, silent and reliable, trouble-free!

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CANADA: Philips Electronics Industries Ltd., Toronto 17

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CIRCLE 83 ON READER-SERVICE CARD

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Miniature Recorders

Ink or Inkless Recording
Permanent-Magnet Moving-Coil Movement
3 Speed Transmission, Hour/Minute Feed
Sensitivity to 250 μa DC without amplification
Rectilinear Recording
Accuracy 1% on DC
4 inch writing width
Easy, instant removal of compact paper transport mechanism

MAXIMUM PERFORMANCE MINIMUM SIZE

Advanced movement design provides big system features in an exceptionally small instrument. Curtiss-Wright Miniature Recorders combine accuracy, simple operation, reading ease, rugged construction and dependable performance with space and weight saving conveniences.

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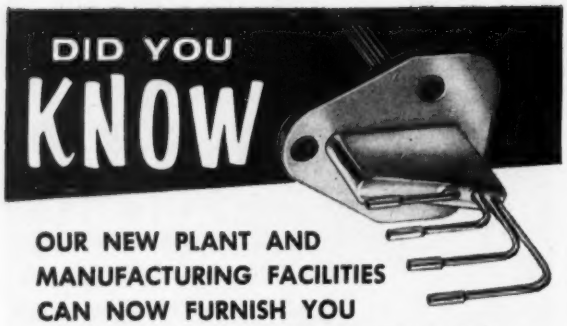

OUR NEW PLANT AND MANUFACTURING FACILITIES CAN NOW FURNISH YOU TOP QUALITY THERMOCOUPLE RAKES

and...

- Temperature and pressure sensing probes for aerodynamic and thermodynamic application.
- A complete line of thermocouple connectors and accessories.
- Custom designed and fabricated assemblies.
- A standard line of thermocouple assemblies available from stock.
- Complete engineering and manufacturing facilities to handle your temperature and pressure problems.

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CIRCLE 85 ON READER-SERVICE CARD

VALPEY TEMPERATURE SENSING DEVICE

- **A SUBMINIATURE QUARTZ-CRYSTAL PRECISION TEMPERATURE MEASURING AND CONTROL INSTRUMENT.**
- **OPERATES OVER A TEMPERATURE RANGE FROM −100°C TO +200°C.**

The Valpey temperature sensing device is a transistorized oscillator whose frequency is controlled by a quartz crystal. Change in frequency due to temperature change is measured to +90 parts per million per degree centigrade change. In conjunction with an accurate frequency measuring device, such as a frequency counter or a crystal filter, a very high sensitivity to small temperature changes is achieved.

In application the Valpey temperature sensing device can control or monitor temperature change at local or remote locations, using telemetering equipment or F.M. transmitters.

Fields of application include: chemical industry, military, commercial, medical and other industries.

For further technical data and pricing write to Electronic Division.

Craftsmanship in crystals since 1931

VALPEY CRYSTAL CORP.
HIGHLAND ST., HOLLISTON, MASS. Tel. GArden 9-4851

CIRCLE 86 ON READER-SERVICE CARD

Voltage Measurements

Differential Voltmeter, Type DC-200AR, has . . . rated accuracy of 0.01% +5 microvolts. A typical accuracy is 0.003% +5 microvolts . . . over a range of 0-1000 V. D. C. . . . The ultra stable Zener reference

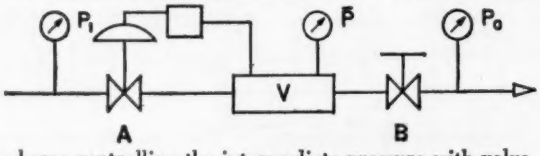
DC-200AR Voltmeter Range	Voltage Applied to Voltmeter	Accuracy of Calibration Equipment
1000 volts	500 volts	.0012%
100 volts	100 volts	.0012%
10 volts	3.053073 volts	.0002%
1 volt	1 volt	.0022%

in this instrument assures 0.001%/year (10 PPM) stability . . . The references are aged . . . for 1000 hours and watched for drift during the period. The Zener reference has a temperature coefficient of less than 2 PPM/C° over the temperature range of +10° to +40°C . . . The second basic source of accuracy . . . is the Kelvin Varley Voltage Divider . . . Typical accuracies are within 0.001%. Resistors used in the dividers, too, are aged several hundreds of hours before matching and installation in the instrument. The temperature coefficient of the resistors in the first deck of the dividers and range switch is 2 PPM/°C . . . The chopper-stabilized detector, which gives full scale sensitivity of 1 MV, is so stable that it requires no zero controls—a real feature in so precise an instrument. Typical drift in this part of the circuit from 20° to 30°C is less than 20 microvolts. The DC-200AR has an infinite resistance at Null, 10 volts and below; 2 megohms above 10 volts . . . (*From 4-page Bulletin 2, Calibration Standards Corp., Subs. Royal Industries, 1025 Westminster Ave., Alhambra, Calif.*)

FOR THIS LITERATURE CIRCLE 227 ON READER-SERVICE CARD

Pressure Control Dynamics

Pressure control systems present a wide variety of component configurations, but in most cases they can be reduced to the elements shown . . . Valve "A" is

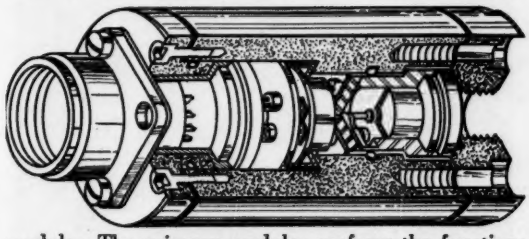


shown controlling the intermediate pressure with valve "B" as the source of load disturbance. As far as the system dynamics are concerned, valve "B" could be working as a back pressure valve with valve "A" introducing the load changes. We could also have each valve controlling its respective downstream pressure as in the case of two stage gas regulation. In this case our analysis would be valid for the loop involving valve "A" (neglecting interaction) and the system controlled by valve "B" would be analyzed by shifting our notation one step downstream. The volume shown between the valves could be a receiver, a short length of pipe, or with admitted error a lumped distribution system . . . (*From 12-page Bulletin TM-7, "Dynamics of Level and Pressure Control," Fisher Governor Co., Box 307, Marshalltown, Iowa.*)

FOR THIS LITERATURE CIRCLE 228 ON READER-SERVICE CARD

Solid-State Strain-Gage Transducer

The new Fairchild 3S-G Pressure Transducer . . . a high precision pressure sensing instrument which can be used with either analog or digital systems . . . consists of three primary modules and two secondary



modules. The primary modules perform the functions of energy conversion, temperature compensation and signal conditioning. The secondary modules perform the functions of the supply regulation and output impedance matching.

Energy conversion is accomplished by a solid-state strain gage sensor which consists of a low mass corrosion resistant diaphragm coupled to bonded (piezoresistive) semi-conductor strain gages arranged as active arms of a Wheatstone Bridge.

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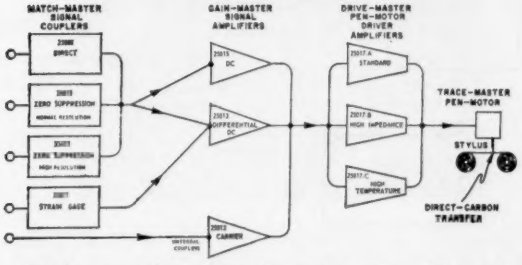
Over pressure, 1.5 times rated full-scale pressure, with zero shift less than ±0.25%; . . . temperature sensitivity, 0.01%/°F; . . . shock capability, 1000 G's without damage . . . (*From 8-page bulletin, Fairchild Controls Corp., Subs. Fairchild Camera and Instrument Corp., 225 Park Ave., Hicksville, L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 229 ON READER-SERVICE CARD

Direct Writing System



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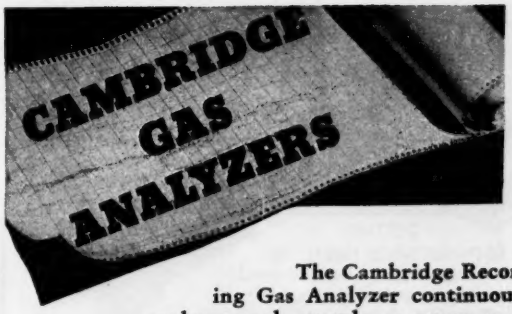

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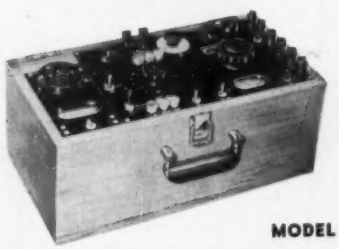

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Bimetal Dial Thermometer

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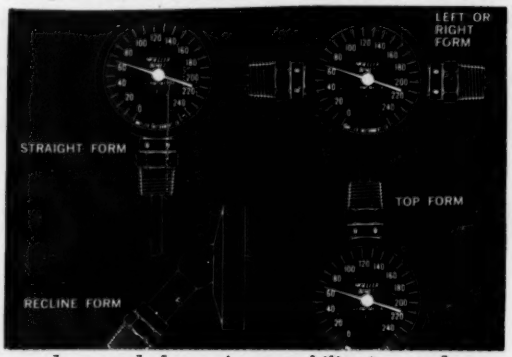
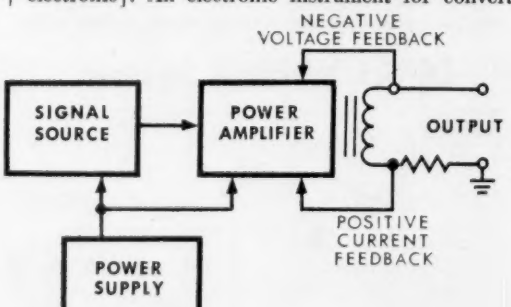


cone dampened for pointer stabilization and more rapid heat transfer. Size and material of the helix is determined by the stem length and temperature range. As a result of the well-balanced design of the helix, shaft and pointer assembly, the thermometer is a rugged instrument with excellent resistance to vibration without sacrifice of sensitivity. It may be temporarily heated well above its normal range without damage to the sensing element . . . Thermometers are individually calibrated in accordance with Bureau of Standards methods; all feature . . . exclusive external "pointer" calibration . . . The accuracy is guaranteed to be within 1% of the scale range . . . (*From* 12-*page Catalog* 225*D, Moeller Instrument Co., Inc.,* 132*nd St. & 89th Ave., Richmond Hill* 18, *N. Y.*)

FOR THIS LITERATURE CIRCLE 231 ON READER-SERVICE CARD

A-C Power Supplies

In•ver'tron (in•vur'tron), n. [coined from inverter + electronic]. An electronic instrument for convert-

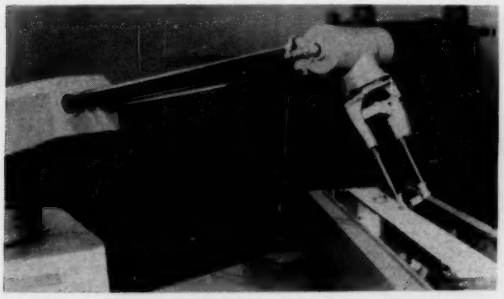


ing a.c. or d.c. electrical energy with one set of characteristics into a.c. electrical energy with a new, specified set of characteristics . . . The Invertron is basically a simple device. The block diagram . . . shows the principle of operation. An oscillator feeds a power amplifier. And that's it. With such a scheme the oscillator is completely isolated from the load, thereby maintaining the integrity of the signal source. The power amplifier employs heavy negative voltage feed back to effect low distortion, low phase shift and low output impedance. Positive current feedback insures a high degree of output voltage regulation despite extreme load variations . . . (*From* 16-*page brochure, Behlman Engineering Co.,* 2911 *Winona Ave., Burbank, Calif.*)

FOR THIS LITERATURE CIRCLE 232 ON READER-SERVICE CARD

Industrial Robot

Designed to speed factory production and to cut costs by taking over repetitive routines now performed by men, Unimate has an arm which duplicates the



functions of the human arm and a "brain" which can remember 200 sequential commands and direct the arm to act in accordance with the stored information . . .

The "brain" is a patented magnetic memory drum, Dynastat, which can be "read" while standing still. Its surface consists of segments of magnetic material which can be either magnetized or de-magnetized in a pattern conforming to instructions recorded when the arm is being led through a task for the first time . . . In addition to controlling the arm and hand, the memory drum also can control external devices . . . (*From News Release, Consolidated Controls Corp., Subs. Consolidated Diesel Electric Corp., 880 Canal St., Stamford, Conn.*)

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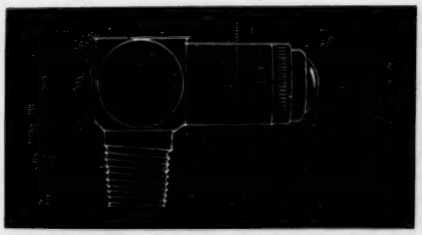
Photoelectric Control

New advantages in using photoelectric devices are being realized daily . . . (1) No mechanical wear normally associated with metal fingers or probes. It



takes no measurable energy to break or reflect a light beam. Hence, maintenance is sharply reduced. Also, very light products that would be damaged by physical contact can now be monitored by a light beam. (2) Electronic amplifiers operate with the speed of light . . . Through unique combinations of timers and pulse stretching circuits, the "presence" of a product being detected can be made to persist for a longer period than the actual scanning time. This permits the use of conventional counting and other circuits which would normally be too slow. Results—considerable financial savings by eliminating more costly, high speed systems . . . (*From 22-page Bulletin 611, Photomation, Inc., Bergenfield, N. J.*)

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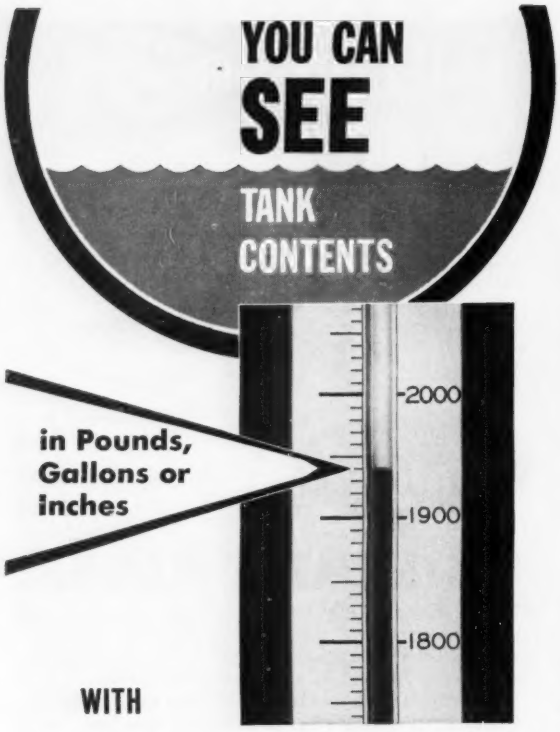

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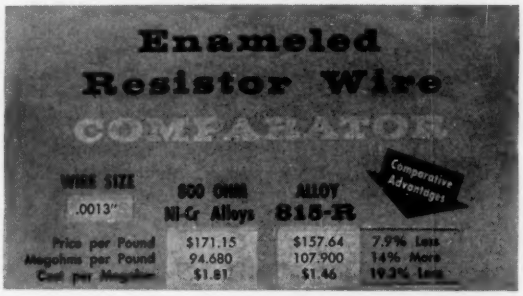
"Cost-Per-Megohm" Calculator

New pocket-size graphic calculator . . . provides convenient means of determining megohms-per-pound and cost-per-megohm of enameled 800 ohm nickel-



chromium and 815 ohm iron-chromium-aluminum precision resistor wire. The handy slide chart covers wire sizes ranging from .0031" down to and including .0004" diameter. Comparative data on wire having a temperature coefficient of resistance of 0 ± 10 ppm per °C over the operating range from —65° to +150°C is given on the front side; wire with a T.C. of 0 ± 20 ppm is presented on the back. To use the chart in calculating resistor costs, simply select the wire size desired and read out current comparative data shown for both types of wire . . . (*Hoskins Manufacturing Co., 4445 Lawton Ave., Detroit 8, Mich.*)

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FLUORIDE, LITHIUM
GALLIUM ANTIMONIDE
GARNET
GERMANIUM
GOLD
INDIUM ANTIMONITE
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CIRCLE 92 ON READER-SERVICE CARD

Bimetal Thermometers

E. R. KEBBON*

Bimetal thermometers feature simplicity, ruggedness and economy. Here are their principles, features, application, response, and accuracy characteristics.

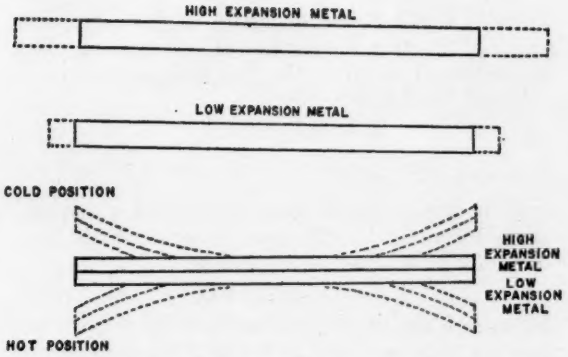

FIG. 1. BIMETAL STRIP bends in this way when heated or cooled.

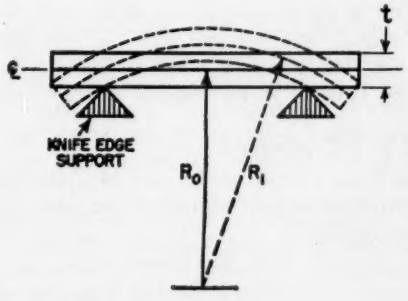

FIG. 2. BASIC relations.

**This work was done while author was with Weston Instruments Division. Mr. Kebbon is now manager of the Electro-Mechanical Systems Department of Curtiss-Wright Corp.*

BIMETAL-ACTUATED thermometers are widely accepted today. Since about 1935 this type of thermometer has been designed and manufactured with enough ruggedness and stability to be acceptable for both industrial and laboratory use.

Over a century ago it was observed that strips of various types of metal, such as platinum, silver, brass or gold, when fastened together side by side, would bend in one direction when heated, and in the opposite direction when cooled. Early applications included correction in chronometers and in some metallic thermometers.

In 1899 *Invar*, a nickel-iron alloy, was discovered during a search for a low-thermal-expansion alloy for use in stable length-measuring standards. Invar, because of its low thermal expansion, was recognized as an ideal material for the low-expansion side of the bimetal pair. Subsequently, nickel-chrome-iron alloys were developed with high coefficients of expansion. Today the most common combinations are alloys made with 20-24% nickel plus 2-4% chromium for the high-expansion side; an equal thickness of Invar with 36-50% nickel content for the low-expansion side.

The components of early bimetals were soldered or brazed, but techniques have been developed whereby the two metals are welded. This led to the safe use of bimetals at temperatures up to 800° F.

Thermostatic Bimetal

When a length of bimetal is heated, the larger change in length of the high-expansion side versus the smaller change in length of the low-expansion side causes the metal to bend, as in Fig. 1.

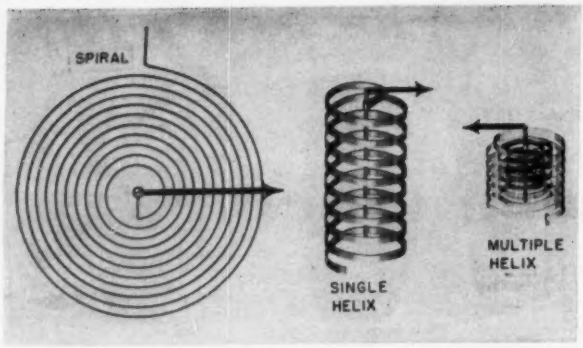

FIG. 3. SPIRAL, single helix and multiple-helix forms. Spiral can produce rubbing between twists. Helix has axial motion. Multiple helix can compensate for axial motion and have large motion.

The thermal activity of bimetal has been named *flexivity** (F), defined by:

$$F = \frac{\left(\frac{1}{R_1} - \frac{1}{R_o}\right)t}{T_1 - T_0} \qquad (1)$$

where R_0 and R_1 are radii of curvature in inches (Fig. 2); t is thickness in inches; and $T_1 - T_0$ is temperature change in degrees F.

Deflection is proportional to flexivity. With one end fixed, the other end of a straight strip moves or deflects an amount proportional to (1) the thinness (inverse of thickness), (2) the temperature change (if operating on the straight portion of the thermal response or deflection-characteristic curve), and (3) the square of the length. Thus, if the length is doubled, the end will deflect four times the original distance; if the thickness is halved, the deflection will double.

If a strip of bimetal is wound into a *helix* or *spiral* and one end is fixed, then the bending action of the bimetal causes rotation of the other end. This angular deflection changes directly with the length of the strip, inversely as the thickness of the material, and in direct proportion to the temperature change (again if operating on the proper section of the thermal curve).

The fundamental relation** between the properties of the two metals or alloys (elements 1 and 2) of a narrow thermostat metal when heated or cooled, may be expressed by the equation

$$\frac{1}{R} = \frac{6(\Delta a)(\Delta T)(t_1 + t_2)\, t_1 t_2\, E_1 E_2}{3(t_1 + t_2)^2\, t_1 t_2 E_1 E_2 + (t_1 E_1 + t_2 E_2)(t_1^3 E_1 + t_2^3 E_2)} \qquad (2)$$

*American Society of Testing Materials "Standard Method of Testing Thermostat Metals" B-106-40.

**Notes from *Thermal Expansion of Solids* by Peter Hidner and Wilmer Souder, Circulars of NBS; also Handbook 77, Vol. III, *Precision Measurements and Calibration*, Dep't. of Commerce, NBS.

where R = radius of curvature of thermostat metal, Δa = difference in coefficients of expansion of elements 1 and 2, ΔT = difference in temperature, t_1 = thickness of element 1, t_2 = thickness of element 2, E_1 = elastic modulus of element 1, E_2 = elastic modulus of element 2.

When the elastic moduli are equal and $t_1 = t_2$, this reduces to

$$1/R = 3(\Delta a)(\Delta T)/4t \qquad (3)$$

where t is total thickness, $t_1 + t_2$.

The coefficients of thermal expansion and the elastic moduli of most materials are not uniform over wide temperature ranges. However, for a limited temperature range the curvature can be expressed by the equation

$$1/R = 2K_s(\Delta T)/t \qquad (4)$$

where K_s is a constant depending on the difference in the coefficients of thermal expansion and on the ratio of the elastic moduli of the two elements.

Cantilever

For a narrow straight strip of thermostat metal fastened at one end and free to move at the other end, the deflection or distance moved by the free end may be represented approximately by

$$d = L^2/2R \qquad (5)$$

where d is the deflection and L is the effective length of the strip. If the value of 1/R from eq (4) is substituted in eq 5, the following equation is obtained for the deflection:

$$d = K_s(\Delta T)L^2/t \qquad (6)$$

Symmetrical U Shape

If the narrow strip of thermostat metal is shaped in the form of a U with arms of equal length, the deflection of the free end is given by

$$d = K_s(\Delta T)L^2/2t \qquad (7)$$

where L is the developed length of the strip.

Spiral or Helical Coil

For thermostat metal shaped in the form of a spiral or helix, the deflection (angular) of the free end is

$$d = K_c(\Delta T)L/t \qquad (8)$$

where L is the developed length, A is the angular deflection in degrees and K_c is a coil deflection constant. This shape is used for restricted spaces and for helix or spiral bimetal thermometers.

Force of a Cantilever

The force exerted at the end of a straight strip of thermostat metal fastened at the other end may be represented by

$$P = K_{ps}\, Dwt^3/L^3 \qquad (9)$$

where P is the force in ounces, w is the width of the strip, D is the deflection in inches, and K_{ps} is a strip torque constant.

Force of a Spiral or Helical Coil

The rotational force of a coil is

$$P = K_{pc}\, Awt^3/Lr \qquad (10)$$

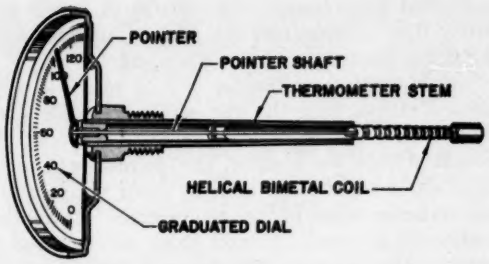

FIG. 4. CONSTRUCTION of an industrial thermometer.

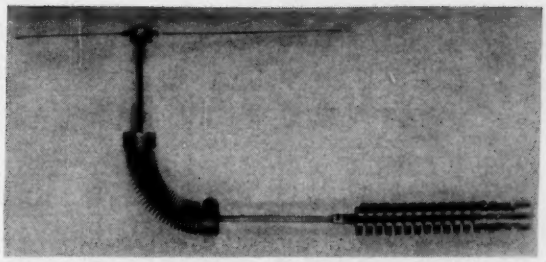

FIG. 5. RIGHT-ANGLE transmission.

where r is the radius to point of force or load application in inches and K_{pc} is a coil torque constant.

Bimetal manufacturers' catalogues list K values for their various types of bimetal.

Thermostat metal is used also in the form of a round disk pressed into a concave or convex shape so that, on heating or cooling, the disk will buckle from one side to the other.

Types of Elements

Three types of elements (Fig. 3) are most commonly used in thermometers—(1) flat spiral type, one of the earliest designs, (2) single helix, and (3) modern multiple helix. Flat strip and other shapes of elements have been used, but these generally are cumbersome and cannot be made sensitive easily.

The flat spiral type of element tends to distort when heated, causing rubbing and hence friction between convolutions and at the bearing. Also, it cannot be mounted readily in a stem that is small enough in diameter to be of practical use.

The single helix moves axially as it winds up or unwinds with heat or cold. This means that clearances must be allowed in the protective housing so that the pointer does not touch the scale or the scale window. If thrust bearings are used to eliminate this condition, excess pressure on them can cause friction. The single helix cannot be made very long or it will sag.

The *multiple helix* element is wound coaxially so as to form coils within coils. The outer and inner helixes are wound in one direction and then in the other from a single strip of bimetal, providing a compact element with compensation for axial motion. This construction can require less immersion depth than other types and permits shorter stem lengths.

After the bimetal strip is wound into its final form, it must be subjected to various stabilizing thermal treatments. These treatments are for stress-relieving purposes only and must not change the physical characteristics of the material.

It is usually recommended that bimetal be heat-treated at a temperature at least 100°F above the maximum temperature at which the element is intended to operate; further, a minimum heat-treating temperature in the range of 400°F to 700°F is recommended, even though the element may be used at some lower temperature.

The torque produced by a bimetal is a function primarily of thickness, length, and type of materials used. Torque gradients available in commercial thermometers range from about 0.01 in-oz per 100° angular rotation of the shaft (for small laboratory-type thermometers) to 0.5 in-oz per 100° angular rotation (for large industrial types).

Construction

The construction of an industrial thermometer using the helical type of bimetal element is shown in Fig. 4. One end of the calibrated element is fastened to the inside of the stem, and a staff or shaft is attached to the other end of the element. The shaft and element are held in the center of the stem by guides and bearings. To obtain fast response, bimetal elements must be made so that there is a minimum of air space between the element and the inside wall of the stem. Element and bearings must be precision made so that the finished thermometer will be free of friction. The pointer is fastened to the top end of the shaft. The thermometer has few moving parts; there are no gears or pinions to require maintenance.

Bimetal thermometers also are made in types that have the dial face parallel to the stem, which means the rotary motion of the element staff or shaft must be transmitted through a right angle to operate a pointer shaft. This has been accomplished in Europe by means of precision bevel gears, but such arrangements have backlash and require a high-torque element to eliminate friction errors. Today the right-angle transmission is accomplished by a long, edge-wound, helical spring which eliminates backlash and requires little torque to operate (Fig. 5).

Selection of Proper Bimetal

There are many different types of bimetal on the market. Some have a low thermal deflection constant (which means a small pointer deflection per degree of temperature change for a given length of element); others have fairly high constants. In general, a bimetal with a low constant is used for

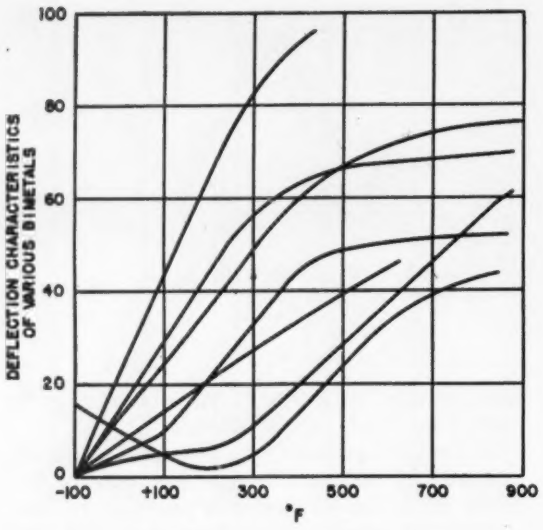

FIG. 6. BIMETAL deflection characteristics.

a long temperature-span, while high-constant bimetal is used for short temperature-spans.

Fig. 6 shows a representative group of bimetal deflection characteristic curves. Note that the bimetal shows uniform mechanical deflection over only a limited portion of the curve. Therefore, to provide a thermometer with uniform scale divisions, one must select a bimetal that has uniform activity over the temperature range desired.

The bimetal strip used in indicating thermometers is usually much thinner than that used in control thermostats.

Ranges

Bimetal thermometers at present can be obtained in ranges from +1000°F down to −300°F, and possibly lower. At these low temperatures the rate of deflection drops off rapidly because the coefficients of expansion of the metals approach each other.

While bimetal thermometers are made in ranges up to +1000°F, the art has not yet progressed to a point where such ranges have long-time stability at these temperatures. Extended exposure to these high temperatures usually cause the characteristics of the bimetal to change, resulting in a shortened scale. This causes the thermometer to read low at the high end, and high at the low end of the scale.

The shortest scale-span of precision, industrial bimetal thermometers today is limited to about 100°F for 300° angular deflection.

It is possible to make bimetal thermometers in more sensitive ranges of higher accuracy, such as the bimetal type of clinical thermometer made in Europe and presently sold in this country. This thermometer has a range of 94° to 108°F for 285° angular deflection, and is graduated in 0.2F-degree divisions. This type of thermometer uses only a small deflection of the bimetal element, which is multiplied by a complicated system of levers and gears; thus it requires the manual operation of pushing a plunger to obtain a reading.

The bimetal thermometer can be made in suppressed ranges, with the low end of the scale starting at 150°, 300°F, or even higher. The only objection is that, on cooling, the pointer will move back around the scale and, at room temperature, can indicate some higher temperature on another portion of the scale. Pointer stops can be used to prevent the pointer from moving back into the high end of the scale but, if the suppression is great, the elastic limit of the bimetal can be exceeded, the element distorted, and errors in calibration can result.

Over-Ranging

In general, bimetal thermometers can be over-ranged without harm. In some cases a room-temperature thermometer can be heated to 400 or 500°F without damage. Manufacturers usually allow a 100% over-range for top readings below 250°F, 50% for those that range up to 500°F, and 10% for ranges up to 750°F.

Calibration and Accuracy

Once an element has been calibrated properly there are few things that can happen to it to cause it to lose its original calibration. However, it is possible for a setting to change with abuse. If this happens, one merely has to reset the pointer mechanically to the proper indication at only one point on the scale, and the thermometer then will be as accurate over the entire scale as it was originally. Some manufacturers provide a simple adjusting screw so that recalibration can be performed without opening the instrument.

Good bimetal thermometers handled with reasonable care will retain their accuracy indefinitely. Usually the larger (industrial) type of bimetal thermometers are guaranteed to be within ±1% of the scale range at any point on the scale; the smaller, faster-acting laboratory or general-purpose types are guaranteed to be within ±½ of 1% of scale range. Better accuracy than this can be obtained if each scale is hand-drawn to match each element, but this would be costly.

It is important that the section of the stem containing the element be completely immersed in the medium to be measured. The sensitive portion of the stem varies, in standard types, from 1¼″ to 3″. When used for gas-temperature measurements, the immersion required may be as much as twice the depth required in liquids.

The stem of a bimetal thermometer using the helical element can be made as short as the element it contains, which means that stems 1″ long are practical for some purposes. Thermometers of this type are being made with stems up to 6′ long, and longer stems are possible. The limit is in the torque gradient of the element. In long stems the weight of the motion-transmitting shaft and the resultant friction at the extra bearings cause inaccuracies, unless larger high-torque elements are used.

Stems and associated external parts are usually made of 18-8 stainless steel. Stainless steel resists corrosion, but has poor thermal conductivity compared to other metals, such as copper. This becomes an advantage in thin-wall stems because poor conductivity has little effect on the response of the thermometer, but does retard conduction of heat up the stem away from the element.

Styles

Bimetal thermometers are made in a large variety of forms from 1″ head diameter to 6″, and even larger. In general, they are divided into two classes: The larger sizes have pipe-thread connections for industrial use, the smaller sizes have smaller-diameter stems, no threaded connections, and are used for general testing or laboratory use.

Bimetal thermometers can carry electrical contacts, drive maximum and minimum hands, or drive small telemetering transmitters. There is a Braille Thermometer used by the blind.

Pointed and screw-or-gimlet-ended stems can be provided. These ends are in mechanical contact with the bimetal element, permitting quick heat transfer.

Thermal Response

The response speed of bimetal thermometers (Fig. 7) is similar to comparable liquid-in-glass thermometers. The mass of the temperature-responsive element, the stem wall thickness, and the air space between the element and the inside of the stem are a few of the factors governing the speed of response. For fast response the bimetal selected must be thin, the stem wall must be thin, and the air space must be small. A small air space means that the bimetal element must be accurately made so that it does not touch the inside of the bore and cause friction.

Fast response can be obtained by exposing the bare element directly to the temperature to be measured.

Bimetal Recorders

With the advent of better bimetal, we are today seeing more recorders of this type appearing on the market. An advantage is that the pen arm can be connected directly to the element, eliminating mechanical levers. Bimetal provides a rugged, dependable, uniform-scale recorder with sufficient torque to overcome friction between paper and pen.

COMING SOON: Survey of bimetal thermometers.

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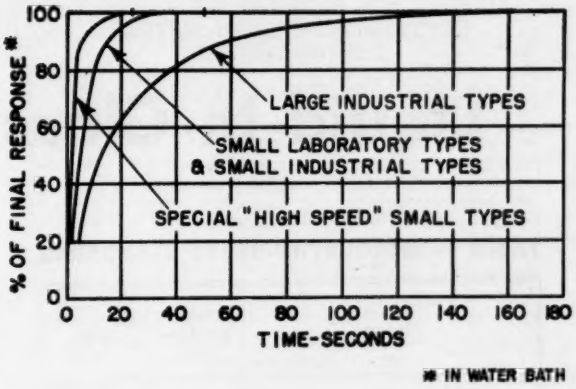
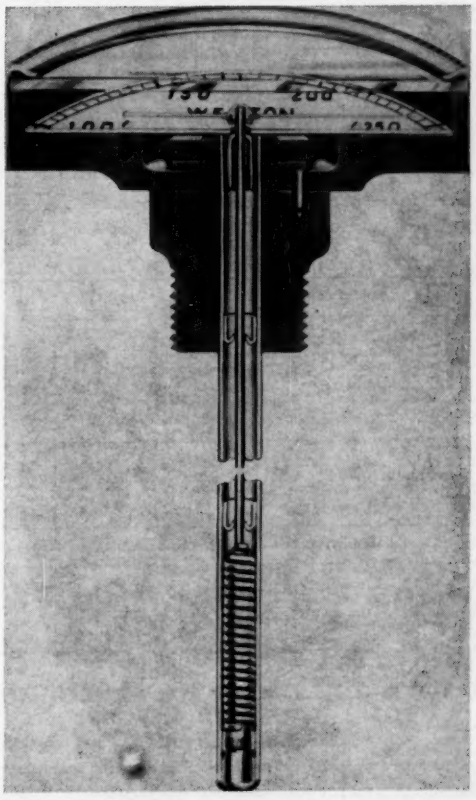


FIG. 7. RESPONSE of bimetal thermometers.



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Liquid-In-Glass Thermometers

TABLE 1—MERCURY-IN-GLASS STANDARDS.

Range	Smallest graduation	Auxiliary scale
°C	°C	°C
0 to 50	0.1	------
0 to 100	0.2	------
50 to 100	0.1	at 0
100 to 200	0.2	at 0
200 to 300	0.5	at 0
300 to 500	1.0	at 0

TABLE 2—TOLERANCES FOR CELSIUS TOTAL-IMMERSION MERCURY THERMOMETERS

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
Thermometers not graduated above 150° C				
° C				
0 up to 150	1.0 or 0.5	0.5	0.1 to 0.2	0.1
0 up to 150	.2	.4	.02 to .05	.02
0 up to 100	.1	.3	.01 to .03	.01
Thermometers not graduated above 300° C				
0 up to 100	1.0 or 0.5	0.5	0.1 to 0.2	0.1
Above 100 up to 300		1.0	.2 to .3	.1
0 up to 100	.2	0.4	.02 to .05	.02
Above 100 up to 200		.5	.05 to .1	.02
Thermometers graduated above 300° C				
0 up to 300	2.0	2.0	0.2 to 0.5	0.2
Above 300 up to 500		4.0	.5 to 1.	.2
0 up to 300	1.0 or 0.5	2.0	.1 to 0.5	.1
Above 300 up to 500		4.0	.2 to .5	.1

TABLE 3—TOLERANCES FOR FAHRENHEIT TOTAL-IMMERSION MERCURY THERMOMETERS.

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
Thermometers not graduated above 300° F				
32 up to 300	2 0	1.0	0.2 to 0.5	0.2
32 up to 300	1.0 or 0.5	1.0	.1 to .2	.1
32 up to 212	.2 or .1	0.5	.02 to .05	.02
Thermometers not graduated above 600° F				
32 up to 212	2 or 1	1.0	0.2 to 0.5	0.2
Above 212 up to 600		2.0	.5	.2
Thermometers graduated above 600° F				
32 up to 600	5	4.0	0.5 to 1.0	0.5
Above 600 up to 950		7.0	1. to 2.0	.5
32 up to 600	2 or 1	3.0	0.2 to 1.0	.2
Above 600 up to 950		6.0	.5 to 1.0	.2

THE LIQUID-IN-GLASS THERMOMETER is probably the most widely used temperature measuring device in both science and industry. In spite of its fragile nature, its relative simplicity makes this type of thermometer singularly attractive where reliable temperature measurements are required but the highest attainable accuracy is not necessary.

The liquid-in-glass thermometer is not an entirely foolproof instrument, however. If the user is to realize the accuracy of which his thermometer is capable, and to recognize its inherent limitations as well, he must have, in addition to its calibration, some knowledge of the behavior to be expected of such a thermometer, the important features of good practice in the design and use of liquid-in-glass thermometers, and the techniques used by the National Bureau of Standards in their calibration. This information is of value not only to those who wish to submit thermometers to the Bureau for calibration, but also to manufacturers, to other standards laboratories, and to those who wish to calibrate their own instruments.

Thermometers graduated on the Fahrenheit scale (F) are calibrated with reference to the International Temperature Scale (C) using the conversion formula:

$$t_{oF} = \frac{9}{5} t_{oc} + 32°F$$

When the highest accuracy is required in a calibration, the thermometer indications are compared directly with temperatures obtained with a standard resistance thermometer. If lesser accuracy is adequate, one of a series of mercury-in-glass standards is used, except below 0°C, where the calibration is always made directly with a resistance thermometer regardless of the accuracy required. The series of mercury-in-glass thermometers which serve as standards for total-immersion comparisons is shown in Table 1.

The scale tolerances allowed in awarding certificates in *total-immersion thermometers* are given in Tables 2 and 3. These tolerances are based on the fact that in the manufacture of thermometers certain small errors in pointing and graduation are inevitable, and also that the indications of thermometers are subject to variations due to the in-

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Abstracts from NBS Circular 600, *Calibration of Liquid-In-Glass Thermometers*, James F. Swindells.

JAMES F. SWINDELLS
National Bureau of Standards

herent properties of the glass. The tolerances must be sufficiently rigid to insure to the user a satisfactory high-grade thermometer and at the same time must not be so rigid as to cause undue manufacturing difficulties.

Partial-immersion thermometers are often used with stem temperatures greatly different than the temperature being measured. For this reason Tables 4 and 5 show that accuracies expected of partial-immersion thermometers are not so high as those for total-immersion thermometers, nor are the calibration corrections stated so closely.

Low-temperature thermometers are frequently designed for use up to room temperature or above. In these cases the vapor pressure of the filling liquid becomes important. A low vapor pressure is necessary to prevent distillation of the liquid at the higher temperatures. Any dye added to improve the visibility of the thermometer liquid should be chosen for good color fastness with respect to light exposure or chemical action with the thermometer liquid. Tolerances applicable to low-temperature thermometers are given in Tables 6 and 7.

A *metastatic* or *Beckmann thermometer* is usually of the enclosed-scale type, so constructed that portions of the mercury can be removed from or added to the bulb permitting the same thermometer to be used for differential measurements in various different temperature ranges. The scales are kept short, usually 0 to 5 or 6°C, although some so-called micro types have a scale of only about 3C°. The "setting" of such a thermometer refers to the temperature of the bulb when the reading is 0° on the scale. When the setting is changed to allow for use at a higher or lower temperature, the quantity of mercury affected by a temperature change is different. It follows that two equal changes in temperature at different settings cause different indications on the scale. Therefore a "setting factor" must always be used to convert reading differences into true temperature differences whenever the thermometer is used at any setting different from the one at which its scale was calibrated. These setting factors combine corrections for the different changes in volume of different quantities of mercury-in-glass scale and the International Temperature Scale.

Tolerance requirements for the certification of Beckmann and *calorimeter* thermometers are given

TABLE 4—TOLERANCES FOR CELSIUS PARTIAL-IMMERSION MERCURY THERMOMETERS.

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy[a] in degrees	Corrections stated to
Thermometers not graduated above 150° C				
0 up to 150	1.0 or 0.5	1.0	0.1 to 0.5	0.1
Thermometers not graduated above 300° C				
0 up to 100	1.0	1.0	0.1 to 0.3	0.1
Above 100 up to 300	1.0	1.5	.5 to 1.0	.2
Thermometers graduated above 300° C				
0 up to 300	2.0 or 1.0	2.5	0.5 to 1.0	0.5
Above 300 up to 500		5.0	1.0 to 2.0	.5

[a] The accuracies shown are attainable only if emergent stem temperatures are closely known and accounted for.

TABLE 5—TOLERANCES FOR FAHRENHEIT PARTIAL-IMMERSION MERCURY THERMOMETERS.

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
Thermometers not graduated above 300° F				
32 up to 300	2.0 or 1.0	2.0	0.2 to 1.0	0.2
Thermometers not graduated above 600° F				
32 up to 212	2.0 or 1.0	2.0	0.2 to 0.5	0.2
Above 212 up to 600	2.0 or 1.0	3.0	1.0 to 2.0	.5
Thermometers graduated above 600° F				
32 up to 600	5.0 or 2.0	5.0	1.0 to 2.0	1.0
Above 600 up to 950		10.0	2.0 to 3.0	1.0

TABLE 6—TOLERANCES FOR LOW-TEMPERATURE TOTAL-IMMERSION THERMOMETERS.

Temperature range in degrees	Type of thermometer	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
Celsius thermometers					
−35 to 0	Mercury	1 or 0.5	0.5	0.1 to 0.2	0.1
−35 to 0	do	.2	.4	.02 to .05	.02
−56 to 0	Mercury-thallium	.5	.5	.1 to .2	.1
−56 to 0	do	.2	.4	.02 to .05	.02
−200 to 0	Organic liquid	1.0	.2	.2 to .5	.1
Fahrenheit thermometers					
−35 to 32	Mercury	1 or 0.5	1.0	0.1 to 0.2	0.1
−35 to 32	do	.2	0.5	.05	.02
−69 to 32	Mercury-thallium	1 or .5	1.0	.1 to .2	.1
−69 to 32	do	.2	0.5	.05	.02
−328 to 32	Organic liquid	2 or 1.0	3.0	.3 to .5	.2

TABLE 7—TOLERANCES FOR LOW-TEMPERATURE PARTIAL-IMMERSION THERMOMETERS.

Temperature range in degrees	Type of thermometer	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
Celsius thermometers					
−35 to 0	Mercury	1.0 or 0.5	0.5	0.2 to 0.3	0.1
−56 to 0	Mercury-thallium.	1.0 or .5	.5	.2 to .3	.1
−90 to 0	Organic liquid.	1.0	3.0	.4 to 1.0	.2
Fahrenheit thermometers					
−35 to 32	Mercury	1.0 or 0.5	1	0.3 to 0.5	0.1
−69 to 32	Mercury-thallium.	1.0 or .5	1	.3 to .5	.1
−130 to 32	Organic liquid.	2 or 1	5	.8 to 2.0	.5

TABLE 8—TOLERANCES FOR BECKMANN AND CALORIMETER THERMOMETERS.

Type of thermometer	Graduation interval in degrees	Allowable change in correction in degrees	Accuracy of interval in degrees	Corrections stated to
Beckmann	0.01° C	0.02 over a 1° interval for setting of 20° C.	0.002 to 0.005	0.001
Bomb calorimeter.	01° C	0.03 over a 2° interval.	005 to .01	.002
Do	.02° C	0.03 over a 2° interval.	.005 to .01	.002
Do	.05° F	0.08 over a 5° interval.	.01 to .02	.005
Gas calorimeter.	1° F	0.15 over a 5° interval.	.02 to .05	.02

in Table 8. Calorimeter thermometers include a specialized group of etched-stem mercury-in-glass thermometers which are used for accurate differential measurements. Since, in the use of these thermometers, the accuracy at any one temperature is of less importance than the accuracy of the temperature intervals, no reference point is required for certification.

Calibration Procedure

When comparing thermometers with liquid-in-glass standards, two standards are always used. In this way reading errors are more readily detected and cross checks of the standards are maintained. Table 9 shows the observations taken in obtaining the corrections applicable to the thermometers at 20°. To simplify the illustration, all of the entries in the table assume perfect thermometer performance and no observer error.

The first observations are the ice points of the thermometers under test. These are entered in the upper part of the table. The thermometers are then mounted in the comparison bath between the two standards, and the power to the bath is so adjusted that its temperature is slowly increasing at a steady rate. The data shown in the table are for a temperature rise of 0.001° between each observation. Two observers (A and B) are used, first with one observer reading and the other recording, and next with the observers interchanged.

The observations are spaced uniformly in time so that with the bath temperature increasing steadily with time, the mean of the observations with any one thermometer will correspond to the mean temperature of the comparison bath during the observations of all of the thermometers. Immediately after the comparison observations, ice points are taken of the two standards. Using these ice-point data together with the known scale corrections for the standards, the temperatures indicated by the standards are calculated and an over-all mean temperature for the observations is obtained. This over-all mean temperature is compared with the mean of the observations with a particular thermometer to obtain a correction to the scale of the thermometer at this point. The thermometer comparisons then are repeated at the next higher test point and so on until corrections are obtained at a sufficient number of points to calibrate the complete scale.

TABLE 9—COMPARISON OF TEST THERMOMETERS WITH LIQUID-IN-GLASS STANDARDS.

	S1	T1	T2	T3	T4	S2
Ice-point readings of test thermometers						
Observer A	-----	+0.02	−0.02	+0.02	0.00	------
Observer B	-----	+.02	−.02	+.02	0.00	------
Mean ice points	-----	+.02	−.02	+.02	.00	------
Thermometer comparisons						
Observer A reading left to right	19.87	19.98	19.96	20.02	20.03	19.89
Observer A reading right to left	19.88	19.99	19.97	20.03	20.04	19.89
Observer B reading left to right	19.88	19.99	19.97	20.04	20.05	19.90
Observer B reading right to left	19.89	20.00	19.98	20.04	20.05	19.90
Means	19.88	19.99	19.97	20.03	20.04	19.89s
Ice-point readings of standards						
Observer A	−0.01	-----	-----	-----	-----	−0.08
Observer B	−.01	-----	-----	-----	-----	−.08
Mean ice points	−.01	-----	-----	-----	-----	−.08
Calculations of corrections						
Correction to standards	+0.12	-----	-----	-----	-----	+0.04
Mean temperature, each standard	20.01	-----	-----	-----	-----	20.01s
Mean temperature of all readings	-----	-----	20.01	-----	-----	-----
Corrections to test thermometers	-----	+0.02	+0.04	−0.02	−0.03	-----

TABLE 10—LAGS IN THERMOMETERS IN A WELL-STIRRED WATER BATH

Type of thermometer	Lag, λ
	sec
Laboratory thermometer, small bulb	2
Calorimeter thermometer, large bulb	5
Beckmann thermometer, large bulb	9
Inclosed capillary portion of Beckmann thermometer	50+

Temperature Measurement by Filled System

Filled-system thermometers use temperature-induced liquid or gas expansion effects. Desired range and application determines the filling media, which can be mercury, gas, liquid, or vapor.

ROBERT C. NELSON, Instruments Publishing Company

TEMPERATURE is a basic process variable, and filled-system (pressure) thermometers do the bulk of industrial temperature measuring, indicating and controlling. Choice of filling fluid makes available many ranges (Table 1). Also, once a fill material is selected, variations in bulb size and shape, length of connecting tubing, compensation, etc., provide narrow or wide spans, various sensitivities, accuracies, and response speeds. Capillary lengths can be up to 200'; only that length needed should be ordered.

The Scientific Apparatus Manufacturer's Association (SAMA) has classified filled-system thermometers into four major classes according to filling material. **Class I** is completely filled with *liquid* (other than a metal, such as mercury) and operates on the principle of liquid expansion. **Class II** is a system partially filled with a *volatile liquid* and operates on the principle of vapor pressure. **Class III** is filled with a *gas* and operates on the principle of gas pressure change with temperature change. **Class V** is filled with *mercury* or mercury-thallium eutectic amalgam and operates on the principle of

TABLE 2—CLASSIFICATION

CLASS	FILLING	FEATURE
I	Liquid	Uncompensated
IA	Liquid	Case and capillary compensated
IB	Liquid	Case compensated
IIA	Vapor	Bulb above ambient
IIB	Vapor	Bulb below ambient
IIC	Vapor	Bulb either above or below ambient (uses large bulb)
IID	Vapor	Bulb above or below ambient—(uses nonvolatile-liquid transmission)
IIIA	Gas	Case and capillary compensated
IIIB	Gas	Case compensated
VA	Mercury	Case and capillary compensated
VB	Mercury	Case compensated

TABLE 1—BASIC FEATURES OF FILLED THERMAL SYSTEMS

	Liquid	Mercury	Vapor Pressure	Gas
Max. Temp.	700°F	1200°F	650°F	1400°F
Min. Temp.	—300°F (usually —125°F)	—60°F (usually —38°F)	—300°F (usually —40°F)	—450°F
Max. Span	600F°	1200F°	400F°	1200F°
Min. Span	10F° (usually 40F°)	25F° (usually 100F°)	60°F (20F° below ambient)	120F° (50F° force balance)
Advantages	Linear scale; Small bulb; Shortest span		Lowest cost; Fastest response; No compensation required;	Lowest temperature; Can withstand greatest over-range; Linear scale; Best for averaging
Disadvantages	Requires capillary and case compensation; Elevation error (especially Hg)		Non-linear scale; Possible elevation error; Trouble or delay as temperature crosses ambient (except IID)	Large bulb; Greatest temperature span required

All illustrations courtesy Scientific Apparatus Makers Association, SAMA Standard RC6-10-1955.

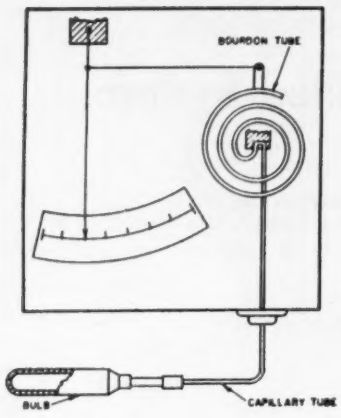


FIG. 1. CLASS I filled-system thermometer uses a liquid filling material.

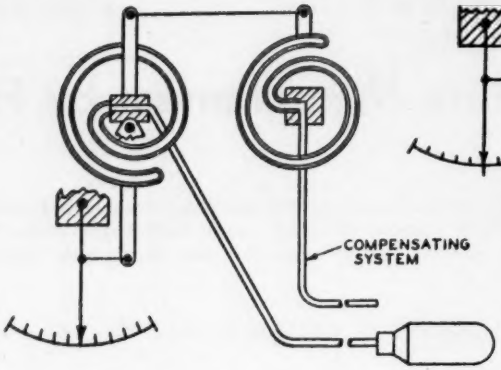


FIG. 2. CLASS IA is a fully-compensated liquid-filled thermal system. The compensating capillary and Bourdon cancel temperature effects at the case and along the capillary.

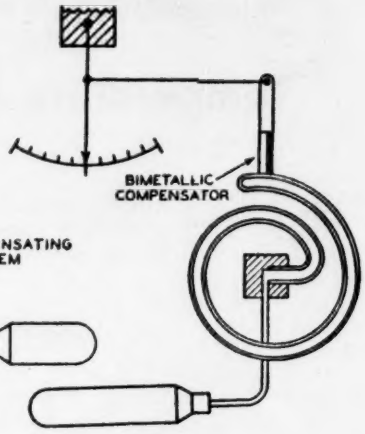


FIG. 3. CLASS IB is a case-compensated liquid-filled thermal system. Compensation usually is with a bimetal strip.

liquid expansion; its features are similar to those of Class I (Table 1).

Liquid (Class I)

Liquid-filled systems (Fig. 1) are the most common.

Liquid fill generally permits smaller bulb sizes and shorter spans between high and low reading—as narrow as 40F°. However, the narrower the span, the larger the bulb. *Scale graduations are uniform.* Fill material usually is an inert hydrocarbon.

The uniform scale is desirable for applications in which temperatures are likely to vary widely over the measurement range, or where temperature and other variables are combined on the same chart, such as temperature and relative humidity in air-conditioning operations.

This system can be furnished with the smallest bulb of any filled thermal system, providing a nominal response time of 6 or 7 seconds. Installation is simplified where space is limited. Without compensation, recommended capillary length is approximately 10′.

A fully-compensated liquid-filled thermometer (Class IA) has two measuring systems (such as two helical elements), one for measurement and the other for compensation (Fig. 2). These are connected together mechanically in opposition. Capillary tubing filled with the same liquid runs from each helical element, through the armored tubing, to the sensitive portion of the bulb. Only one capillary tube is connected to the bulb. The other is closed at the bulb end. Both capillary tubes are subjected to the same temperature. The compensating capillary tubing and the compensating helical element automatically correct for temperature changes along the tubing and in the case.

Class IB is compensated only at the case—usually by a bimetal strip (Fig. 3)—and is adequate when case and capillary are at the same temperature.

A difference in elevation between bulb and measuring element can lead to an error due to the static head. Any sizable difference in elevation should be specified so that it can be allowed for in factory calibration, or else eliminated by field calibration.

When To Use Class I (Liquid-Filled) Thermometers

From Product Data No. T801-4,
The Bristol Company, Waterbury 20, Conn.

A Class I thermometer will likely be best if (a) your answer to the first 3 questions below is "yes," and (b) your answers to at least two of the other 7 questions is "yes":

1. **Is the range you want to measure within −125°F and +500°F?**
2. **Is a uniformly-graduated scale acceptable?**
3. **Is the arithmetic product of capillary ambient temperature span (in F degrees) and tubing length (in feet) less than 10,000?**
4. **Is the product of capillary ambient temperature span (in F degrees) and tubing length (in feet) less than 200?**

Note: If your answer to the fourth question is "yes," you can use element compensation only. However, if the product is over 200 but less than 10,000, you should use a fully-compensated (Class IA) thermometer.

Example: A thermometer is to be ordered with 40′ of tubing. This tubing will be at ambient temperatures from 50 to 80°F. The capillary ambient temperature span is 80°F −50°F = 30 F°; 40′ x 30 F° = 1200. As 1200 is between 200 and 10,000,

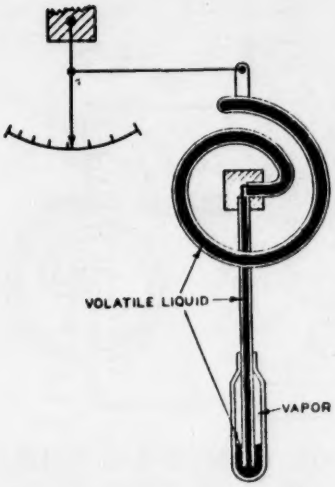


FIG. 4. CLASS IIA is a vapor-pressure thermal system designed to be used when bulb temperature is higher than ambient temperature. Liquid-vapor interface in the bulb establishes pressure of the liquid in the capillary and measuring element.

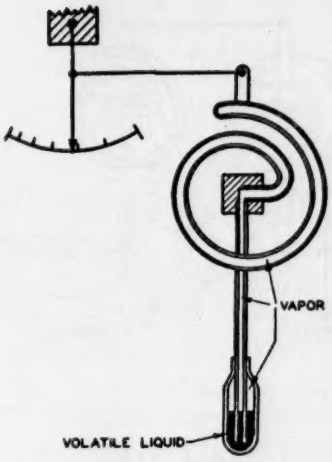


FIG. 5. CLASS IIB is a vapor-pressure system designed to be used when bulb temperature is lower than ambient temperatures. Capillary and measuring element contain the vapor; the liquid is entirely in the bulb.

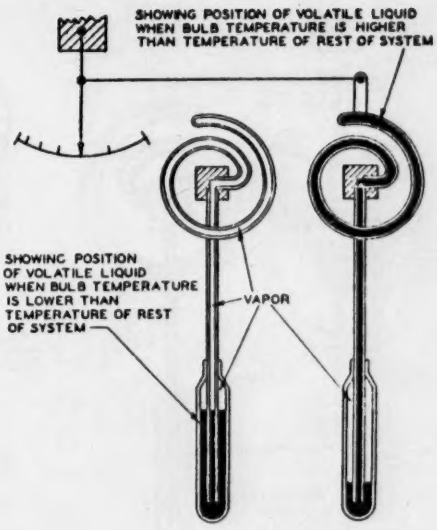

SHOWING POSITION OF VOLATILE LIQUID WHEN BULB TEMPERATURE IS HIGHER THAN TEMPERATURE OF REST OF SYSTEM
SHOWING POSITION OF VOLATILE LIQUID WHEN BULB TEMPERATURE IS LOWER THAN TEMPERATURE OF REST OF SYSTEM
VAPOR

FIG. 6. CLASS IIC vapor-pressure system is designed to be used when bulb temperature varies above and below ambient temperature. Bulb must be large enough to accept liquid from the measuring element and capillary when its temperature goes below ambient temperature.

a fully-compensated (Class IA) thermometer should be specified.

5. **Is the temperature span you want to measure less than 100 F°?**
6. **Does the range you want to measure include the normal ambient temperature span?**
7. **Do you require the shortest bulb length?**
8. **Is there a large difference between bulb elevation and case elevation?**
9. **Do you want high accuracy throughout the range?**
10. **If the thermometer is a controller, will it normally control at some point in the lower half of its temperature range?**

Vapor-Pressure (Class II)

A vapor-pressure system is only partly filled with a volatile liquid. The vapor pressure *at the interface* (in the bulb), which is a function of temperature, establishes the pressure throughout the closed system. Thus compensation for temperatures along the capillary is unnecessary.

Filling media include methyl chloride, sulfur dioxide, butane, propane, ether and hexane. Different media are used for different ranges. Temperatures from −40°F to +600°F can be measured handily; one maker offers a vapor-pressure line that goes down to −300°F.

The vapor-pressure system has the fastest response (4 to 5 seconds) of all pressure thermometers, and is the lowest in price. Temperature span can be as narrow as 60 F°, and one maker reports spans down to 20 F°.

At low temperatures, the vapor pressure changes much less per degree than it does at high temperatures. Therefore, the temperature graduations at the low end of a Class II scale will be closer together than the graduations at its upper end. This makes reading easier at the high end of range, and also makes a Class II system provide high sensitivity and accurate measurement for short temperature spans—at the high end of the range.

There are four types of Class II systems:

Class IIA (Fig. 4) is for applications where the bulb temperature is always *above* ambient temperature. The capillary and bourdon will be full of liquid.

Class IIB (Fig. 5) is for applications where the bulb temperature is always *below ambient* temperatures. The capillary and bourdon will hold only vapor.

Class IIC (Fig. 6) is for use where the measured temperature may at times be either *above or below* the ambient temperature. The bulb is larger than than necessary for Classes IIA and IIB because it must be large enough to hold all the liquid in the system.

The Class IIC system is *delayed in action* when measured temperature crosses the ambient temperature. When the bulb goes from, say, below ambient to above ambient, the vapor throughout the capillary must condense. The capillary must be filled with liquid and the interface must again be entirely in the bulb before the system indicates properly. This introduces a lag that is eliminated by the Class IID (dual-filled) system.

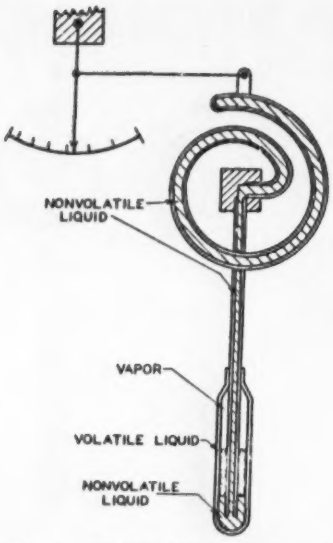


FIG. 7. CLASS IID is preferred design for same applications as Class IIC. Pressure is transmitted by non-volatile liquid; all the volatile liquid (and interface) always remains in the bulb.

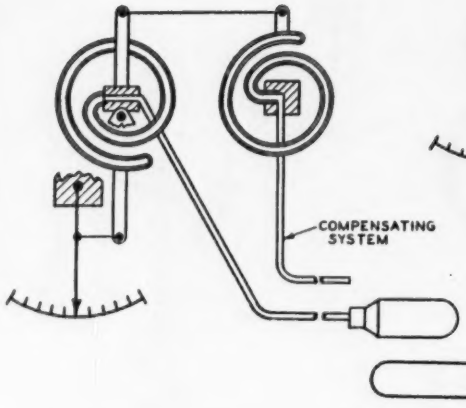


FIG. 8. CLASS IIIA gas-filled system is fully compensated.

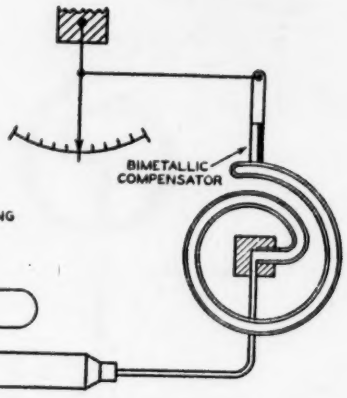


FIG. 9. CLASS IIIB gas-filled system is case compensated only.

Class IID (Fig. 7) also is for measuring temperature *at, above,* and *below* ambient temperatures. All the volatile liquid remains in the bulb regardless of temperature. A second, relatively non-volatile liquid is used to transmit the vapor pressure to the measuring element. Bulb temperature can cross ambient temperature with no interruption in indication.

Class II systems are subject to an elevation error only if the capillary contains liquid.

When to Use Class II D (dual-filled) Thermometers

From Bulletin 09-200-C Weston Instruments Div., Daystrom, Inc.

When the span of the particular vapor-pressure instrument is determined, the application of the following rule will determine whether or not the system should be the dual-filled type:

Take 20% of the span (F° difference between high and low point) and subtract it from the index number 90. If the remainder is above or equal to the low point of the range, the system should be dual filled. If it is below, it should not.

Example 1: Range 70 to 150° F = 80° span
20% of 80 = 16
90 −16 = 74.
74 is above the low point of the range, therefore the system should be dual filled.

Example 2: Range 70 to 220°F = 150° span.
20% of 150 = 30
90 −30 = 60.
60 is below the low point of the range; therefore the system should not be dual filled.

Gas (Class III)

Gas systems are used primarily for low and high temperatures. They are filled with an inert gas, usually nitrogen, or helium. Temperatures down to −450°F and up to 1400°F can be measured with available systems. Nominal minimum span is about 400 F°, but helically-wound thin-tube bulbs are available for spans of 120 F°. Gas systems can suffer the greatest over-range—from 150% to 300%—without harm.

Gas systems usually have a large bulb, which makes full compensation unnecessary—as long as the volume in the capillary is negligible by comparison.

Class III A (Fig. 8) is a fully-compensated gas system.

Class III B (Fig. 9) is a gas system with case compensation only—usually with a bimetal strip.

There is no Class IV because there was no unanimity as to what Class IV meant when the committee established these standards. The committee omitted all reference to Class IV. Classes I, II, III and V had substantial uniformity of use and no known instances of contractictory use that might lead to serious difficulty.

Mercury (Class V)

Although mercury is used as a liquid, convention and application factors have considered mercury-filled systems separate from liquid-filled systems.

Mercury provides rapid response (second to vapor), power, and accuracy. It does not amalgamate with, or wet, ferrous alloys and thus flows rapidly through capillary tubing made of such material.

Mercury provides the greatest choice of span widths, with minimum widths of 100 F°. Above 600°F mercury bulbs can be smaller than that with other fills.

Mercury-filled systems are available to 1200°F, but most suppliers provide up to 1000°F as the

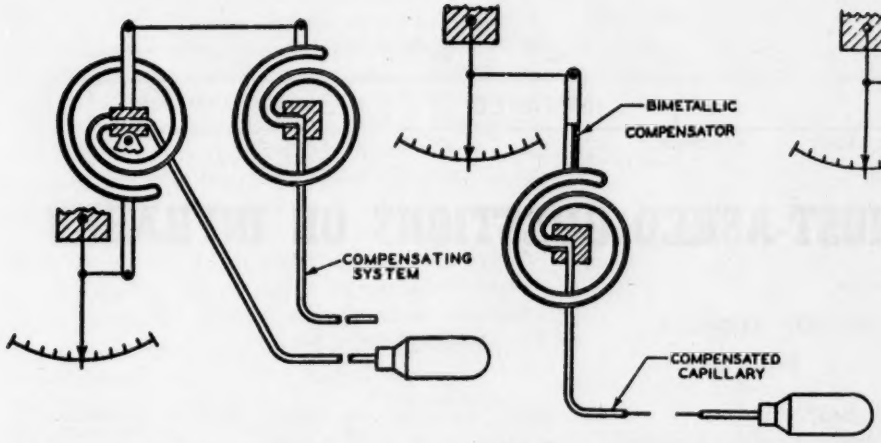


FIG. 10. CLASS VA mercury-filled system can be fully compensated as shown at left. Alternative method uses bimetal strip for case compensation and separate capillary compensation comprising a special (Invar) wire inside the capillary. Expansion of the mercury in the capillary is compensated by expansion of the tubing.

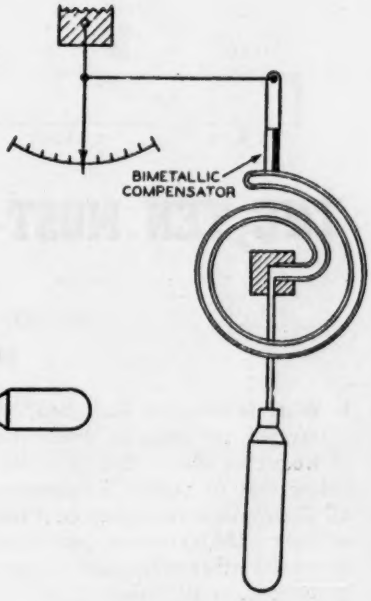


FIG. 11. CLASS VB is mercury-filled system with case compensation only.

upper limit. In this region mercury vaporizes, and recalibration is recommended after recycling mercury into its vapor phase. Available minimum temperatures are down to —60°F.

Class V A is fully compensated; Fig. 10 shows two methods. In the second method the Invar wire runs through the capillary.

Class V B (Fig. 11) is case compensated.

Thermometer wells are used often because mercury is toxic and harmful to some industrial products. There should not be much difference in height between the bulb and the measuring device.

Wells

Thermal wells provide a pressure-tight receptacle to receive a bulb. Wells are required when corrosion, high velocity, abrasion, erosion, or hazardous conditions exist, or whenever it is desirable to remove a bulb without interrupting the process. Wells are available in brass, bronze, stainless steel (Types 304, 347 and 316), carbon steel, nickel, titanium, Monel and Hastelloy. Flanged wells usually are supplied when sheathed wells of Tantalum, glass, lead or silver are required.

A well retards response speed. Several makers offer means to insure metal-to-metal contact between the bulb and well.

Bulbs

Bulbs are made of various materials to withstand corrosion and abrasion. Materials include copper, chrome-plated copper (or tinned), Types 304, 347 and 316 stainless steel, mild steel, carbon steel, wrought iron, Monel, Ambrac, Everdur silicon bronze, and Hastelloy. Protective lead sheathing can be telurium lead, tin lead, antimony lead, or Nalco lead. Bulbs can be joined rigidly to their mounting (flange or union), or connected by an extension that can be bent.

Sensitivity is inversely related to the cross-section of the bulb; a large cross-section requires more time for heat to penetrate to the center. Thus the smaller the cross-section the better the sensitivity. Also, the more surface area a sensing bulb has, the greater will be its sensitivity.

The most sensitive bulbs are made of thin tubing that can be wound into a helix. The helix then can be extended across a duct or oven to sense an average temperature. Such bulbs are called *averaging bulbs.*

Non-standard bulb shapes are specified for three possible reasons:

(1) *Space limitations*—when the shape of a standard bulb will not fit.

(2) *Increased sensitivity*—when need for additional sensitivity requires small cross-section and elongated shape.

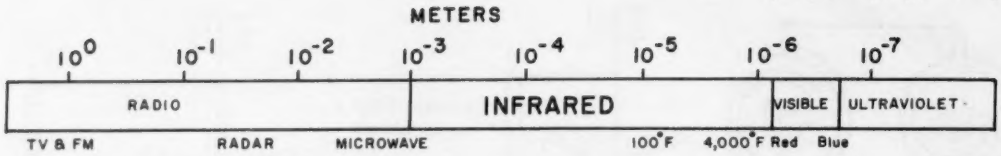
(3) *Temperature averaging*—when an elongated bulb is required in order to sense an average temperature over a wider area.

Refilling

Most manufacturers agree that damaged systems should be returned to the factory for refilling and recalibration. Usually, refilling requires purging, exhausting and precise filling that requires special equipment that only a manufacturer has available.

The only possible exception seems to be a helium gas (Class III) system which a user might refill from a helium bottle. He must then recalibrate.

COMING SOON: A SURVEY OF EQUIPMENTS



THE TEN MOST-ASKED QUESTIONS ON INFRARED

BURTON BERNARD

Radiation Electronics Co.
Div. of Comptometer Corp.

1. What is Infrared Radiation?

Infrared radiation is electromagnetic radiation of frequency above that of radio frequencies and below that of visible frequencies (Fig. 1). Like all electromagnetic radiation, it travels at the speed of light (186,000 miles per second), and can be measured either in frequency or wavelength (usually microns, or 10^{-6} meter).

2. Does a Substance Have To Be "Hot" To Emit Infrared Radiation?

No. All objects emit infrared radiation which is related to the temperature of the object. Only at absolute zero (—273° C) will an object cease to emit any radiation, including infrared radiation. The following formula shows the relationship between the total energy emitted by an object and its temperature:

$$W = \epsilon\sigma T^4 \qquad (1)$$

where W = radiant flux density; ϵ = emissivity factor (discussed in Question 5); σ = Stefan-Boltzmann constant (5.67 x 10^{-12} watts/cm^2-deg^4); and T = absolute temperature in degrees Kelvin.

3. Does The Amount Of Infrared Radiation Vary With Temperature?

Yes. Infrared radiation is emitted over a wide band of wavelengths, but the amount of energy emitted at any one wavelength increases as the temperature is increased (Fig. 2). The wavelength of the energy peak decreases as the temperature is increased. Mathematically:

$$\lambda = \frac{2.96 \times 10^3 \text{ microns}}{T} \qquad (2)$$

where λ = peak wavelength in microns, and T = temperature in degrees Kelvin.

4. What Is A Blackbody?

A blackbody is a surface or object which completely absorbs all of the radiant energy striking it. According to Kirchoff's Law, the radiant absorption (A) of an object must equal the radiant emittance of that object, or:

$$A = \epsilon \qquad (3)$$

As there are no perfect blackbodies found in nature, an emissivity factor ϵ must be determined to solve for W in Equation 1.

5. What Is Emissivity?

Emissivity is the ratio of the radiant energy emitted by an object at a temperature T to the radiant energy emitted by a blackbody at the same temperature T. This can be written as:

$$\epsilon = W_o/W_{bb} \qquad (4)$$

where ϵ = emissivity factor, W_o = energy emitted by an object at a temperature. W_{bb} = energy emitted by a blackbody at the same temperature.

6. What Is the Relationship Between Emissivity, Reflectivity, Transmissivity, and Absorptivity?

If an object does not absorb all of the radiant energy falling upon it, it must reflect and/or transmit the remaining energy. The sum of absorptivity, (A), reflectivity (R), and transmissivity (T) must equal 100% of the total incident energy, or

$$A + R + T = 1 \qquad (5)$$

$$A = \epsilon = 1-(R + T) \qquad (6)$$

7. Does Emissivity Vary With Wavelength?

The emissivity of some objects does change with wavelength. The amount and direction of change of the emissivity factor varies with different types of materials. Fig. 3 shows a few common materials and their respective emissivity factors at various wavelengths.

8. How Can Infrared Energy Be Detected?

There are two general classifications for infrared detectors—one is the *thermal detector* and the other is the *photodetector.*

Operation of the *thermal detector* is based on the change of a physical property (such as resistance or thermoelectric force) of the detector as its own temperature is changed. Examples of thermal detectors are thermocouples, pneumatic detectors, and bolometers.

The infrared *photodetector* is a semiconductor which produces a signal proportional to the photon flux which strikes its sensitive element. Photodetectors include photoconductive, photovoltaic, and photoelectromagnetic detectors. Two types of photoconductive detectors are shown in Fig. 5. The detectivity of a photodetector can be increased by cooling.

Both thermal and photo detectors are used frequently with an optical system employed to focus the radiant energy onto the sensitive element. The thermal detector, which has a uniform spectral response to infrared radiation, does not respond as rapidly to thermal changes as does the photodetector. Fig. 4 shows the relative response curves of some of the more familiar types of detectors being used today.

9. Is There Any Limit On The Range At Which An Object's Temperature Can be Measured By An Infrared System?

For normal industrial applications the maximum range depends only on the size of the object and the resolution angle of the infrared optical system. For example the Thermodot TD-1 (Fig. 6) has a resolution angle of less than ½ degree and can resolve a spot size approximately 1″ by 1″ at a distance of 10 feet, or 2″ by 2″ at 20 feet, etc. If the object is not completely resolved, its radiant energy will be integrated with the surrounding energy and result in a temperature reading different than that of the object. If, however, the temperature and resolved area of the surroundings are known, then an accurate temperature reading can be determined at any distance.

10. Does The Amount Of Emitted Infrared Energy Vary With Angle?

Yes. As stated in Lambert's Law, the radiant energy emitted by some objects and surfaces in any one direction varies as the cosine of the angle between the normal and that particular direction. That is:

$$W_\theta = W_n \cos \theta \qquad (7)$$

where W_θ = total energy emitted in any one direction; W_n = total energy emitted in a normal plane; θ = angle between the normal and direction of emittance.

However, as the radiation thermometer does not "see" a point source, but resolves a definite spot size, the area resolved increases by cos θ as the angle from the normal increases, or

$$A_\theta = A_n/\cos \theta \qquad (8)$$

where A_θ = area resolved at a given angle to the normal; A_n = area resolved at the normal.

From equations 7 and 8 it can be shown that for any given temperature, regardless of the angle of incidence, the amount of flux density detected by the radiometer will remain the same because

$$P_n = W_n A_n \qquad (9)$$

where P_n = radiant power emitted in a normal plane (watts); W_n = radiant emittance at a normal plane (watts/cm²); A_n = area resolved in a normal plane (cm²).

By substitution:

$$P_n = W_\theta A_\theta \cos \theta/\cos \theta \qquad (10)$$

$$P_n = W_\theta A_\theta = P_\theta \qquad (11)$$

FIG. 2

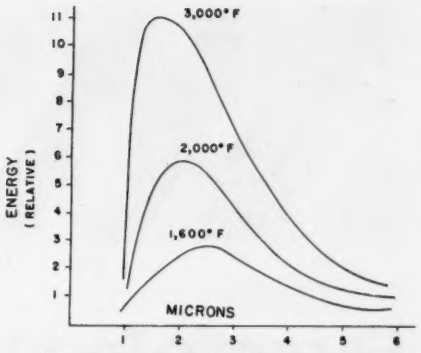


FIG. 3

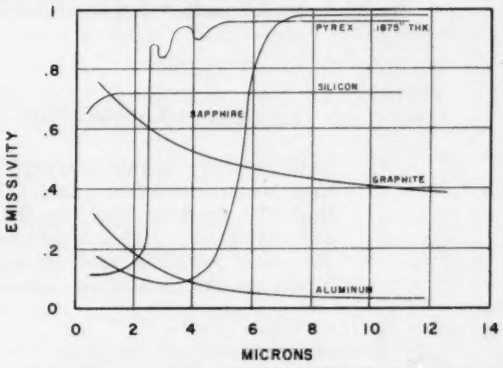


FIG. 4

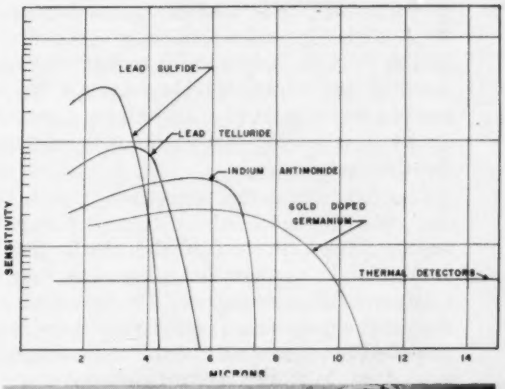


FIG. 5

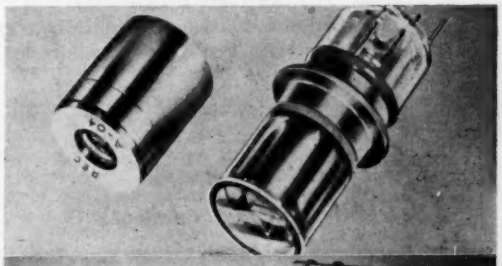
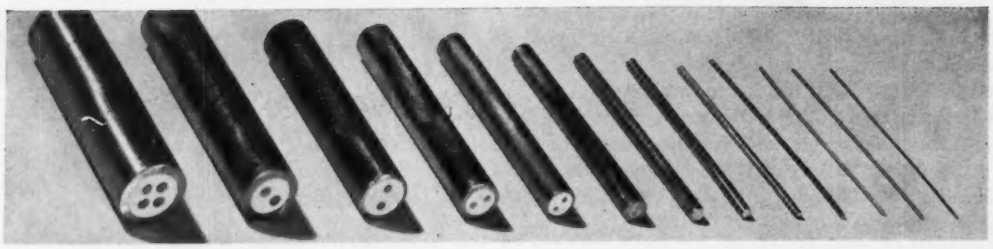


FIG. 6



Ceramic-Insulated Thermocouples

L. SCADRON Aero Research Instrument Co., Inc.

New advances in manufacturing techniques have made it possible to manufacture ceramic-insulated metal-sheathed wires using large-diameter initial tubing that will produce long lengths to close electrical and physical tolerances without splices. Special assemblies, such as triaxial and bitriaxial thermocouples are now possible and practical. Using the old techniques, they are not. Voids in the insulation are non-existant in multiple-pass drawn material.

CERAMIC-INSULATED metal-sheathed wires are being used increasingly in thermocouples. As the markets have grown, so has confusion because of the conflicting claims made by various manufacturers as to what constitutes a proper process for constructing and testing a thermocouple or sheathed conductor.

One difficulty is the many factors to be considered. Should the sheath be thin so that it can be readily stripped in the field (but the insulation falls out)? Should the sheath be heavy so that the insulation is fully compacted (but the wire is smaller than in the thin-walled unit)? Should the sheath be annealed in argon (but the tubing was initially annealed in hydrogen before processing to get it bright)? What about high potential tests to ground? Insulation resistance voltages? Helium leak tests for sheath integrity?

Before the best compromise solution can be offered and reasonable specifications developed, the recent advances in the field should be considered.

Recent Advances

There have been many advances in technological development. Only a few years ago it was felt that all AerOpak* type material should be produced in the same manner as heating elements, using the standard single-reduction swaging process to compact the insulation. However, advances in both materials and techniques during the last two years now make possible *multiple-pass drawing* which gives an improved product at a lower cost.

There is excellent justification for multiple pass drawing. Tubing is generally made by redraw mills from purchased draw stock tubing, welded or seamless. A mandrel is inserted and the tube is multiple-pass drawn down to the final size. At various points (depending on the amount of reduction) full anneals are given to the tube-mandrel combination. Wire is made in a similar manner. In AerOpak, the ceramic acts as a mandrel for the tube and a die for the wire. This technique, combined with full solution annealing temperatures compatible with the materials, gives calibration consistency, stability and long sheath life.

Annealing to remove the effects of cold working the materials has also been improved to a point where a multi alloy assembly such as Chromel/Alumel** wire in an Inconel*** sheath can be stress relieved, recrystallized (annealed), and the grain size controlled by selecting the proper temperature for the proper time, and controlling the cooling rate. Note: any method of fabrication requires subsequent anneal to remove the effects of cold working on the sheath and wires.

Perhaps the best advance of all is in the *calibration consistency of multi-drawn assemblies.* Example: in 2000 individual surface-temperature thermocouples supplied for one of the largest solid-fuel missile programs, extremely accurate calibration data measures within $\pm 1°F$ of the zero error curve; this consistency was virtually impossible prior to development of multi-draw procedures. This consistency is obtainable after many repeated exposures of the assembly to temperatures exceeding 1800°F.

New processes have almost eliminated old problems such as damaged wires, radial and longitudinal cracks in the sheaths caused by wall thickening,

*TM Aero Research Instrument Co.

**TM Hoskins Mfg. Co. ***International Nickel Co.

TABLE I—PHYSICAL CHARACTERISTICS AND SUGGESTED TOLERANCE OR TEST

A. Outside diameter of sheath—e.g., ±0.001".

B. Roundness of sheath (considered important from the standpoint of sealing around the O. D. when used in standard tube fittings, and through drilled holes)—e.g., ±0.001" total indicated reading.

C. Surface finish of sheath (for sealing and fitting purposes)—e.g., commercial finish 32 RMS.

D. Actual wall thickness (for machining, welding and ease of bending without loss of insulation or splitting of sheath)—e.g., 10% of O.D. minimum; 15% for hand-packed insulation.

E. Actual wire diameter—e.g., ±0.001".

F. Spacing, wire to wire, wire to sheath and radially (to insure the ability to attach connectors and locate junctions within probe assemblies; twist per foot if orientation of junction and connection is important)—e.g., equal spacing between wires and between wires and wall; twist 30°/ft maximum.

G. Minimum permissible radius about which material may be bent (to insure the ability to form complex probes without loss of insulation resistance)—e.g., twice the sheath diameter.

H. Roundness and finish of wires—e.g., round and smooth, showing only slight imbedment of insulating material in wire.

I. Sheath integrity (cracks, splits, inclusions and porosity)—e.g., certify either hydrostatic pressure test, or dye-penetrant check, or steam-check test[1], or electrical test, or helium leak test.

J. Uniformity of these properties along the entire length—e.g., tests are applicable to full length.

K. Stability of these properties under service conditions—tests specified by user.

TABLE II—ISOTHERMAL ELECTRICAL PROPERTIES AND SUGGESTED TOLERANCE OR TEST

A. Insulation resistance, wire to ground—e.g., 50 or 500 volts DC (megger).

B. Insulation resistance, wire to wire—e.g., Hipot (high potential voltage to ground) at 80 volts/mil of insulation to check for contamination and/or voids in insulation.

C. Resistivity of the individual wires—e.g., resistivity for wire type and gage specified (Kelvin or Wheatstone bridge). This also checks continuity.

D. Purity of the insulation material[2]—chemical analysis of insulation material (can be certified by manufacturer).

E. Uniformity of these properties through the entire length—tests are applicable to full length.

F. Stability under service conditions—tests specified by user.

TABLE III—THERMOELECTRIC PROPERTIES AND SUGGESTED TOLERANCES OR TESTS

A. EMF versus temperature and tolerance—e.g., ISA limits, either standard or special for thermoelectric elements specified (can be certified).

B. Uniformity of calibration along the entire length—e.g., homogeneity check (NBS circular 590) ±200 microvolts maximum deviation (expensive).

C. Stability under service conditions.

and variation in the wire location inherent in the swaged compaction process. However, all the old techniques should not be dismissed summarily. In some special designs a combination of either swaging or drawing, or rolling and drawing, has yielded the best results, giving maximum compaction of the insulation without damage to the wires or sheath.

Techniques also have evolved that make possible combinations of sheath and wire such as Chromel/Alumel contained in a copper sheath. The wires can be annealed individually within the sheath without raising the sheath to a temperature that would cause excessive oxidation or grain growth.

Specifications

Several technical societies are working to produce a standard specification for ceramic-insulated thermocouples. A military specification (MIL-T-22300—Ships) has been issued. It allows each manufacturer to specify his processes on an order, and allows changes in the processes after submission of the change in writing and a review by the contracting agency. A common characteristic of this MIL specification and other user specifications is that the cost of the quality assurance tests often exceeds the cost of the material itself!

At present, many users have written specifications governing the characteristics of the end product and also the process. There is a disadvantage connected with user process specifications: By specifying one process, the user fails to gain the advantage of the advances of technological development.

Ideally, the user should specify the following:

(1) Type of wire material. (2) Number of wires. (3) Type of sheath material. (4) Type of insulation and (5) Length and O. D.

Information about the *physical characteristics* of the materials then is necessary to permit the design of probes and connectors to accept the material, and to insure that machining and welding operations can be carried out. These are listed in Table 1.

Resistance properties change with temperature and therefore must be ascertained at pertinent temperature levels. Resistance properties can be affected by fabrication such as bending, or by adverse service conditions, and must be tested accordingly for the characteristics listed in Table II, along with suggested tests or tolerances.

Information regarding the *thermoelectric properties required* is necessary to insure proper interpretation of the junction temperature from the output EMF. These are listed in Table III.

Footnote 1—Steam Chest Test

Immerse sheath in a wet steam atmosphere at 30 psig for 30 minutes, cool to room temperature by flooding with cold water. Cut 6" at each end and discard. Check insulation resistance of AerOpak. If ends are dry, insulation resistance should read 5 x 10^7 ohms minimum for a 20' length. Ends can be welded over to prevent moisture penetration before steam check if desired, but must be cut off to complete insulation resistance check unless hot junction end is underground.

Footnote 2

In reactor applications, the presence of certain trace impurities in the insulation can affect the behavior of the reactor and the thermocouple in the reactor. In these applications information is required as to the concentration of materials of high capture cross-section. In addition, certain elements can cause rapid failure of thermoelements and must be controlled:

1. Sulfur
2. Carbon
3. Boron (or equivalent boron)
4. Hafnium
5. Iron Oxide
6. Calcium Oxide
7. Copper
8. Lead
9. Tin
10. Zinc

Here is a supplier's standard specification (ECS/60-M1) for metal sheathed ceramic-insulated thermocouples. Military Specification MIL-T-22300 (ships) "Thermocouples, Metal Sheathed, For Nuclear Reactors" is being revised. Correspondence is invited on this controversial subject.—Ed.

Swaged MgO Thermocouples

EARLE C. SMITH
E. C. Smith Mfg. Co.

IT IS the intent of this specification to include the types of thermocouples comprising an integral and continuous metal sheath surrounding tightly compressed magnesium oxide insulation and one or more conducting wires. Aluminum oxide and zirconium oxide may be included except for lower temperatures and lower resistance tests.

1. PROCESSING

1.1 The metal sheath shall be swaged from a larger starting diameter to the final diameter in a single operation. The starting size shall not be greater than the following to reduce to the nominal final size:

Starting O.D.	Nominal Final O.D.
0.084"	1/16" (0.0625")
0.160"	1/8" (0.125")
0.250"	3/16" (0.1875")
0.313"	1/4" (0.250")

Explanation:

Repeated reduction builds up extreme internal sheath stresses which result in internal wedge-shaped cracks. These cracks, if extending to the outer surface, are rejected at the factory. However, interior sheath cracks due to repeated reduction which do not extend to the surface may open up in service due to thermal cycling and cause failure of the thermocouple.

Repeated reduction also damages wires, causing wide diameter variations, shape changes, changes in homogeneity, etc. These effects have been the subject of considerable investigation.

Repeated reduction methods are used only to cut material costs; by so stretching the thermocouple it is possible to cut material costs to the order of 10c per foot for 1/16" size compared to approximately $1 per foot for SPS (single-pass swaged) material. SPS processing is recommended.

More than one stage of reduction requires annealing at the sheath anneal temperature. This is never the same as the required anneal temperature for the thermocouple wires, and each thermocouple wire has a different annealing schedule. Thus, the wires are under or over-annealed, and their future life and stability are seriously affected even though an initial calibration may be satisfactory.

Let us consider an extreme case of platinum *vs* platinum 10% rhodium wires in an Inconel* sheath. The sheath may require annealing at 1950°F, the platinum at 1,550°F, and the platinum 10% rhodium at 2,450°F. Thus, we would find the platinum somewhat over-annealed and the platinum 10% rhodium under-annealed. Any further size reduction (which also means elongating the wires) would be detrimental to the thermocouple wire properties of grain size, tensile strength, aging characteristics, and stability.

2. SHEATH

2.1 Sheath diameters shall be held to the following tolerances when measured at any point over the length:

Nominal O.D.	Tolerance
1/16" (0.0625")	+0.0015, −0.001"
1/8" (0.125")	+0.002, −0.001"
3/16" (0.1875")	+0.0025, −0.002"
1/4" (0.250")	+0.003, −0.002"

Explanation:

While closer tolerances can be held on special runs, it is an advantage to the user to allow the manufacturer to determine the final O.D. within the above tolerances based on raw-material tolerances. For example, a typical run includes suppliers' tolerances as follows: tubing with ±5% tolerance on wall thickness, ±0.002" on diameter, insulators with ±0.002" on O.D., and ±0.0015" on holes and wires with ±0.0005". It is obvious that maintaining finished quality is not a simple matter. Wider tolerances than those given may mean that the user may not be able to use standard adjustable mounting fittings or compression fittings to slide over the sheath.

2.2 Wall thickness shall be controlled to fall within the following limits in the finished thermocouple:

Nominal O.D.	Wall Thickness
1/16" (0.0625")	0.009" to 0.012"
1/8" (0.125")	0.011" to 0.015"
3/16" (0.1875")	0.014" to 0.022"
1/4" (0.250")	0.020" to 0.030"

2.3 The sheath tubing is to be of the type specified by the purchaser and in seamless type unless otherwise indicated by the purchaser. Certified mill analysis reports shall be supplied upon request.

*T. M. International Nickel Co.

Explanation:

Certain special alloys are commercially available only in strip which is formed into welded and drawn tubing. All of the most commonly used materials, however, are available in seamless grades. The references to mill-analysis reports prevents the use of beverage-grade stainless tubing and odd or off-spec types which may be picked up from some jobbers' stocks. Prices for such low-grade tubing may be only 40% of the price of first-grade tubing of the same analysis which is produced with mill-analysis reports.

2.4 The sheath surface shall be free of cracks, gouges, scratches or marks of any sort and shall exhibit a finish equivalent to 32 microinches or better.

3. INSULATION

3.1 Unless otherwise specified, the insulation used shall be electrical-furnace fused magnesium-oxide (MgO) in compressed preformed crushable beads.

3.2.1 The insulation purity shall be at least 99.4% MgO.

3.2.2 The boron content of the magnesium shall not exceed 30 PPM average analysis.

3.2.3 All lime content to be complexed as silicates.

3.2.4 Total metals content not to exceed 0.1% and iron oxides content not to exceed 0.12%.

Explanation:

A great deal of confusion is prevalent concerning insulation. MgO is generally preferable above 1,000°F because of its higher resistance. Aluminum oxide or zirconium oxide may be satisfactory for lower temperatures or in large diameters at higher temperatures.

Much has been made of extreme purity requirements. Alumina of 99.6% purity is readily available at standard prices. However, we know from research work that certain "impurities" can raise the high-temperature resistance as much as 10 times. We also know that other impurities can cause extremely low resistance values.

The boron content of MgO must be held to a minimum in most nuclear work, but the figures for boron content requirement have been lowered (on paper) with each engineer who has written a specification. If 50 ppm is good, 40 ppm is better; if 40 is good, 20 is better, and so on until we get to some requiring 5 ppm. At the recent 2-day Symposium on MgO conducted at General Electric Research Laboratory, two of the leading spectroscopists (specialized in boron determination) indicated that it is possible to make an analysis with a certainty only of the order of plus or minus 10 to 15 ppm.

4. WIRES

4.1 The wire sizes in the finished thermocouple shall be:

Nominal O.D. of Thermocouple	B & S Gauge	Wire Size	Tolerance
1/16"	28	0.0126"	±0.001"
1/8"	22	0.0253"	±0.001"
3/16"	18	0.040"	±0.0015"
1/4"	16	0.051"	±0.002"

Explanation:

It is common knowledge that stability and life are proportional to wire size—larger wires hold up longer. The user should always use wires as large as consistent with his other requirements.

For additional information refer to: "Stability of Base-metal Thermocouples in Air from 800 to 2,200°F." A. I. Dahl, National Bureau of Standards; pg. 1238-1266, *Temperature: Its' Measurement and Control in Science and Industry*, Reinhold Publishing Corp.; and S.A.E. #158A *Basic Studies on Base-Metal Thermocouples*, J. F. Potts, Jr. and D. L. McElroy, ORNL.

4.2 When thermocouple wires are used (including I.S.A."K". calibration) only ±3/8% tolerance or better premium grades shall be used. Vendor shall supply on request, reproduction of manufacturer's tags taken from wire coils used in fabrication.

Explanation:

Occasionally complex-alloy thermocouple wires are redrawn and annealed by thermocouple manufacturers in the interest of economy only. As pointed out previously, the annealing schedules for thermocouple alloys are unique, and the special properties of top-grade wires are lost in such processing. Since any working of these wires may be harmful, it makes sense to start with the best material obtainable.

5. ANNEALING

5.1 Where bright anneal is specified, the entire thermocouple assembly is to be heated in argon or vacuum to the annealing temperature for the sheath alloy (±25°F), held for 15 minutes, and cooled to 500°F or lower within one minute. Copper-constantan and copper wires are excluded.

5.2 Air annealing where indicated by purchaser shall be performed per schelude as in 5.1.

6. END SEALS

6.1 All exposed ends shall be sealed with a waterproof electrical compound which shall be cured or dried to a hard form bonded securely to the sheath.

6.1.1 Where specified by purchaser, the ends sha!l be sealed by welding. If one end is fabricated into a hot junction, the end to be bared shall be indicated by excess weld bead of approximately 50% larger diameter than sheath, or by bending ½" length to 90° angle.

Explanation:

The high resistances required of a good thermocouple cannot be maintained if the end seals are not completely moisture-tight. Sometimes strippable coatings of the military protective type or cements which will transmit moisture are used, simply to provide easy removal by the user. These seals will not provide adequate moisture protection, and the time saved in removing seals is lost by the need to "bake out" the piece. A good seal must bond firmly to the metal, and it is often necessary to cut off ⅜" or ¼" of sheath to remove the good seal.

7. INSULATION RESISTANCE

7.1 The insulation resistance of the swaged thermocouple before and after annealing shall be at least 10^{12} ohms x foot (1,000,000 megohms x foot) when measured at 500 v DC at room temperature with an instrument of at least ±10% accuracy. This resistance shall be measured between wires and between each wire and sheath. When requested, the resistance readings shall be supplied to the purchaser. The polarity shall be reversed without appreciable difference in resistance reading.

Explanation:

Often we see in a manufacturer's literature or in specifications a statement that the "thermocouple material has a resistance between wires and sheath of 10 megohms"—or some similar figure. Such statements are meaningless.

The resistance figures must at least include a temperature figure and length dimension. For example, if the leakage resistance is 10^{12} ohms-foot at 700°F, a 33′ length will have resistance:

$$\frac{10^{12} \text{ ohms} - \text{ft}}{33 \text{ ft}} = (3)\,(10^{10}) \text{ ohms}$$

Leakage resistance decreases with length because each leakage path is in parallel with all others.

Reversal of polarity is necessary to eliminate materials showing marked capacity effects. We have checked some materials from other sources showing "resistance" changes as high as 100 to 1 when reversing polarity. A capacitance specification might be included here, but this would require additional equipment many users may not have. Since the effect is a gross effect, it is quite easily checked by a resistance measurement, regardless of whether an electronic megohmmeter or hand-cranked "megger" is used.

7.1.1 The insulation resistance tests of 7.1 shall be performed at elevated temperatures of 1,000 and 1,800°F, and the median resistance shall be:

Temperature	Median Resistance	Minimum Resistance
1,000°F	300 megohms x ft	100 megohms x ft
1,800°F	100,000 ohms x ft	50,000 ohms x ft

Explanation:

The most difficult problem with swaged thermocouples is maintaining sufficiently high resistance. A room-temperature resistance measurement is *not* adequate. Often, an allowable resistance of 10 or 50 megohms degenerates to a few hundred ohms or less at elevated temperatures. Keep resistances high at both room and high temperatures. Sometimes lower test voltages are included in specifications for room temperature resistance testing. *DO NOT* permit lower voltages than 500 volts DC for high resistance measurements. If a manufacturer contends this damages his product, the product is no good.

8. SPURIOUS E.M.F.

8.1 A length of finished thermocouple without hot junction and with 12" heated to 1,600°F shall not produce an output greater than 100 microvolts.

Explanation:

The fact most generally withheld from users is that *all* swaged type thermocouple materials produce spurious voltages. We know that the sheath introduces a third alloy, and we also know that the wires-to-sheath resistance drops with temperature. These facts combine with certain known and unknown impurities and various effects of ion and electron movements to produce what has been called the distributed Seebeck voltage as well as other voltage generation. Lumped together, this is called the spurious emf, and this exists along the heated length with *no* connection between the thermocouple wires. An error figure of 100 microvolts represents 4° to 5°F error in a Chromel-Alumel* thermocouple, and this may be measured on an instrument such as a Sanborn or Brush recorder. Mr. Ralph Freeman, Aircraft Nuclear Propulsion Department, General Electric, Cincinnati, has presented papers on this subject.

9. CONTINUITY

9.1 All wires shall be checked for end-to-end continuity and shall not show a resistance reading higher than that calculated for the actual wire diameter and length.

10. SHIPPING

10.1 Lengths of 20 ft and less shall be shipped straight unless otherwise specified.

10.2 Where coiled lengths are required, coil diameters shall be no less than:

1/16" — 24"	3/16" — 48"
1/8" — 30"	1/4" — 60"

Since no technical society or company has any complete alloy code we developed a system, using the principle of color bands similar to the way resistors are coded. We use ¼″-wide adhesive plastic tapes in eight colors. Our current color code identifies 16 calibrations, 5 insulations and 41 sheath alloys.

Comments by J. Nanigian, Nanmac Corporation

"These comments pertain to the wire sizes as noted under para. 4 of this article."

"Assuming the thermocouple wires are equally spaced in their sheaths, then the proposed specification would result in only 0.004″ and 0.015″ of insulation between the wires and the tube wall in the 1/16″ O.D. and 1/8″ O.D. thermocouples, respectively. With due regard to the fact that larger wires hold up longer, large wires are not always desired. In enclosed thermocouples this is not important anyway."

"I would suggest two sizes of thermocouple wires in each nominal size of wire. For the 1/16″ and 1/8″ thermocouples I suggest thermocouple wires of about 0.006″ and 0.015″ diameter, respectively. The main advantage would be to minimize electrical shorts at the cold-junction end of the thermocouples by allowing more space between the sheath and the wires. Additional advantages would be faster response (because of smaller junctions), smaller errors due to thermal conduction in the wires, and perhaps cheaper cost—especially when using platinum and expensive alloys."

"For the 3/16″ and 1/4″ O.D. thermocouples I would suggest standard-size smaller-diameter wires for both as optional items. Perhaps 0.0253″ wires can be used in both. This would reduce final costs (because of using standard small wires), minimize inventory of raw materials, and may simplify fabricating the thermal junctions. The cost of 0.051″ diameter platinum and special alloys may make the final costs of the thermocouples unnecessarily high."

J. Nanigian
Nanmac Corp.
Indiana Head, Md.

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*T. M. Hoskins Manufacturing Co.

Thermoelectric Properties of Rhodium-Platinum Alloys

Here is a review of the thermoelectric properties and behavior of rhodium-platinum alloys of various composition.

A. S. DARLING

Johnson Matthey & Co., Ltd.
(J. Bishop & Co.)

THERMOELECTRIC PROPERTIES of rhodium-platinum alloys have been the subject of fundamental and industrial concern since the pioneer work of Le Chatelier in 1886. Holborn and Wien demonstrated the high stability of rhodium-platinum thermoelements over the period 1892-1899, and concluded that the 10% rhodium (Le Chatelier couple) compared favorably with the platinum resistance thermometer for accurate temperature measurement. Commenting on the extremely rapid growth of industrial pyrometry, Henning and Moser remarked that at the Physikalish Technische Reichanstalt alone, 9915 rhodium-platinum thermocouples were calibrated between 1900 and 1930.

Fig. 1, taken largely from Caldwell's data, illustrates the thermoelectric force in millivolts generated between rhodium-platinum alloys and pure platinum at various temperatures. An important feature of these curves is the reasonably flat plateau displayed at lower temperatures by alloys containing 20 to 50 atomic percent of rhodium. No evidence of a phase change within the dotted area has yet been advanced.

The Le Chatelier thermocouple was in general use until 1922, when tests carried out by the U. S. Bureau of Standards showed that 10% couples of British manufacture were less stable than their American counterparts. Chemical analysis indicated the presence of up to 0.34% of iron in the British alloy. Improved refining methods eliminated the iron, with the result that 13% of rhodium was required to develop an emf comparable to that of the American 10% couple. The 13% couple was found to be very stable, and is generally preferred in England to the 10% couple, which gives a lower emf. British Standard 1826, 1952, defines the emf generated by the two couples at temperatures up to the melting point of platinum. The values are based largely on determinations carried out by C. R. Barber at the National Physical Laboratory, and represent average values maintained by manufacturers for many years before 1950.

Since 1927 the 10% rhodium-platinum/platinum thermocouple has been used to define the International Temperature Scale over the interval from 660°C to the melting point of gold.

Contamination Effects

The high temperature-stability of rhodium-platinum thermocouples is adversely affected by contamination, by slight preferential vaporization of rhodium, and by gradual diffusion of rhodium into the pure platinum limb. Although ultimate failure is usually due to attack by metallic or other vapors, prolonged heating at temperatures in the region of 1500°C can lead to appreciable change in calibration.

Lead and zinc vapors and sulphur-bearing gases frequently cause brittleness and hot shortness, and thermocouples should be protected by impermeable sheaths against such contaminants.

Rhodium-platinum alloys have a great affinity for silicon.

At temperatures above 1000°C reducing conditions tend to break down silicious refractories, thus liberating silicon which attacks the noble metal. Intimate contact between metal and refractory is not essential because the reaction can progress through the silicon monoxide vapor phase. The melting point of a thermocouple contaminated by silicon in such a way may be as low as 1200°C. Complete avoidance of silicon is difficult because even the purest oxide refractories are not completely free from this element. Experience has shown that the incidence of attack depends largely on the reduction potential of the atmosphere rather than on the silicon content of the refractory.

Abstracted from *Platinum Metals Review*, a quarterly publication on platinum technology, published by Johnson, Matthey & Co., Limited, and available in the U. S. from J. BISHOP & CO., Platinum Works, Malvern, Pennsylvania—a Johnson Matthey Associate.

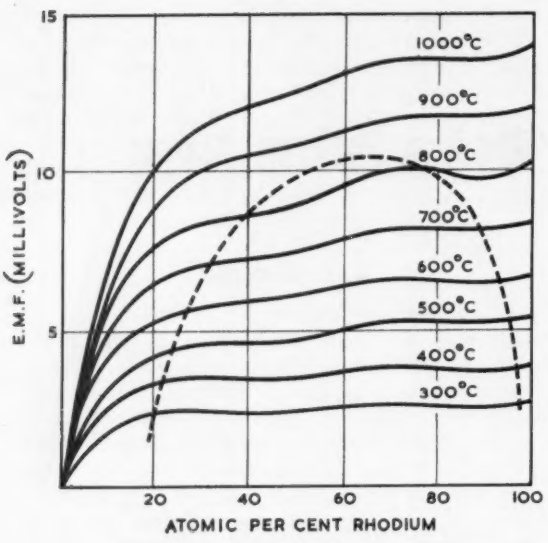


FIG. 1. THERMOELECTRIC FORCE in millivolts generated between rhodium-platinum alloys and pure platinum at various temperatures.

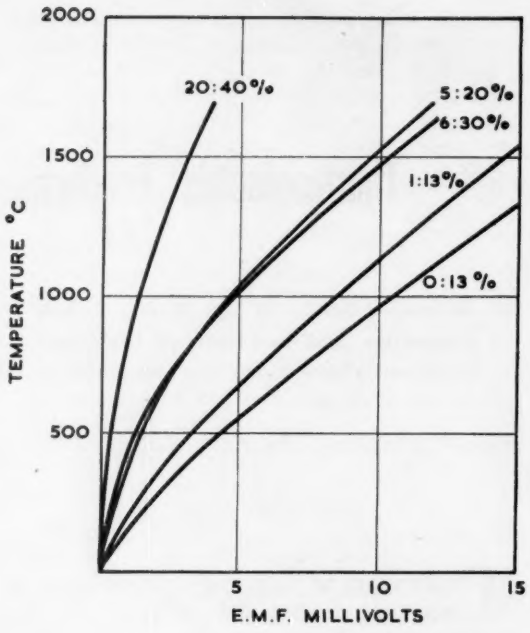


FIG. 2. CALIBRATION CURVES of 1:13, 5:20, 6:30 and 20:40% rhodium-platinum thermocouples compared with that of the standard 13% rhodium-platinum couple.

Silicon attack can, however, occur even when conditions do not appear to be reducing. Research on this problem was stimulated by the frequent thermocouple failures encountered soon after the general introduction of the quick-immersion technique for liquid-steel temperature measurement. Land and Reeve confirmed that contamination did not occur in the absence of traces of oil. The complete mechanism of silicon transfer was finally established by Chaston, who showed that embrittlement was caused by the sulphur present in traces of oil left in the thermocouple. This sulphur, in the presence of carbon monoxide, reacts with the refractory to produce volatile silicon sulphide, which dissociates on the surface of the couple wires to form brittle silicide. The silicide forming in the rhodium alloy is a hard constituent with a bluish tint, while that in the platinum member is softer and grey in appearance. A further crystal boundary constituent is frequently found in the rhodium alloy. These three silicides have been studied microscopically and by X-ray diffraction techniques. A contraction of lattice parameter indicates a slight solubility of silicon in platinum, but the exact composition of the silicide phases has not been precisely determined. This type of attack can, in practice, be avoided by baking out the steel protection tubes at dull red heat in the presence of a current of air.

Prolonged heating in air in the complete absence of sulphur frequently can induce appreciable change of thermoelectric force even though mechanical failure need not occur. The pure platinum limb of the couple is generally most affected by this type of deterioration. Chaussain reported that whereas at 1300°C, silica and alumina affected the thermoelectric characteristics of pure platinum considerably more than those of the rhodium-platinum alloy, thoria appeared to be inert to both couple legs. Tests by Ehringer led to similar conclusions. At 1400°C in air, the resistance to attack by pure alumina, mullite or silica increased with rhodium contents up to 30%, which was the richest alloy studied. Although reducing conditions accelerated the rate of attack, rhodium alloys in contact with pure alumina were not contaminated appreciably. Lapp and Maksimova confirmed the high stability of rhodium alloys heated in contact with alumina for long periods at 1500°C.

Additional tests with alumina, beryllia, magnesia and thoria showed that all these refractories were equally stable towards rhodium-platinum, and that the most stable alloy contained 30% of rhodium. Experiments by Bennett had results which suggested that couple deterioration of this type may be primarily induced by impurities in the refractory rather than by the refractory itself.

Evaporation of Rhodium and Platinum

Rhodium and platinum both evaporate from the surface of heated noble metal thermocouples, although the effect of such evaporation on the calibration is frequently exaggerated. Bennett, for example, has heated a complete platinum/13% rhodium-platinum thermocouple between terminals in

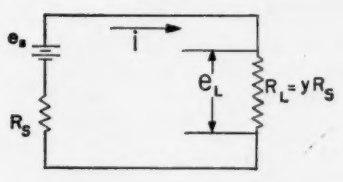
free air at 1500°C for 30 hours. Although a total loss in weight of 16.5% occurred, the emf generated at the gold point had decreased by only 3°C. Data on the relative evaporation rates of rhodium and platinum from couple wires are rather contradictory. Mrs. McQuillan, as a result of tests carried out at 1600°C, concluded that platinum evaporated slightly more than rhodium. Jewell and Knowles reported a slight preferential evaporation of rhodium. The more recent results of Raub and Plate indicate that rhodium evaporates from the alloy less readily than platinum.

Rhodium Diffusion

A gradual diffusion of rhodium into the pure platinum limb is probably the most important factor contributing to the deterioration of thermocouples heated for long periods above 1400°C. Very slight contamination of the pure platinum limb by rhodium results in a pronounced decrease in the emf generated by the couple. Rhodium is transferred from the alloy limb of the couple by (1) diffusion through the hot junction and (2) evaporation, the latter effect being predominant. Evaporation of rhodium from adjacent furnace windings often contributes to the deterioration of the pure platinum couple limb.

Small additions of rhodium frequently are made to the pure platinum limb to minimize the effects of rhodium diffusion. Although such additions lower the couple emf, its thermal stability is greatly improved. The 1% rhodium-platinum/13% rhodium-platinum thermocouple sometimes is used in England, while the 0.5% rhodium-platinum/13% rhodium-platinum thermocouple is used to a limited extent in America. Such rhodium additions minimize the susceptibility to attack by refractories and increase the high-temperature mechanical properties. Considerations of this type suggest that the rhodium content of the negative couple limb might be considerably increased. The alloy combination selected should be one in which the emf generated is as high as possible, and the melting point of the limb poorer in rhodium also is as high as possible; three rhodium-platinum thermocouples of this type are now in general use. British practice favors the 5% rhodium-platinum/20% rhodium-platinum couple as having the best general properties, while the 6% rhodium-platinum/30% rhodium-platinum thermocouple is used in Germany.

The 20% rhodium-platinum/40% rhodium-platinum thermocouple is suitable for use up to 1900°C and has been used for measuring the temperature of oxygen-blown stainless steels. Fig. 2 contrasts the calibration curves of these couples with those of the standard 13% rhodium-platinum couple. Because these special couples generate very low emf at room temperature, cold junctions and compensating leads are not generally required.



THERMOCOUPLE LOADING— An Exercise in Impedance Matching

W. E. BOSTWICK, Lawrence Radiation Lab.

If we express load resistance (R_L) as a function of source resistance (R_s), the error due to source resistance is easily calculated. Let e_s be the thermoelectric voltage, R_s the junction resistance, and R_L (including lead wire resistance) be expressed as a fraction of R_s:

$$R_L = yR_s$$
$$e_s = iR_s + iyR_s$$
$$e_L = iyR_s$$

We are interested in the ratio e_L/e_s as y increases from zero.

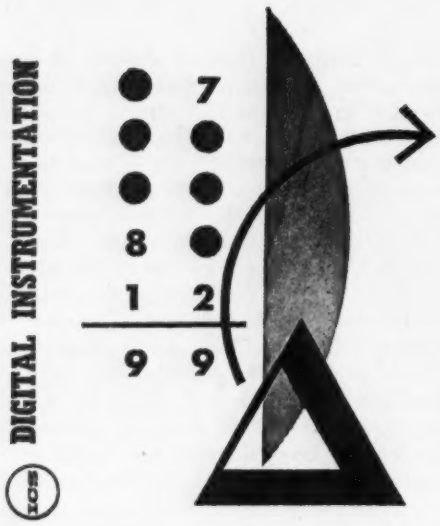
$$\frac{e_L}{e_s} = \frac{iyR_s}{e_s} = \frac{iyR_s}{iR_s + iyR_s} = \frac{y}{1+y}$$

Thus $e_L = e_s\left(\frac{y}{1+y}\right)$

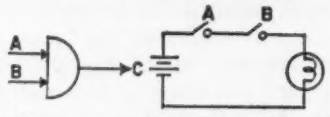
The term $y/(1+y)$ expresses the fraction of the open-circuit source voltage that appears across the load. Thus (Table), if load resistance is 100 times source resistance, the load voltage is 99% of the open-circuit source voltage. If the load resistance equals the source resistance, the load voltage is ½ the open-circuit source voltage (the condition for maximum *power* transfer from source to load).

TABLE

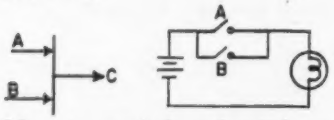
y	$\frac{y}{1+y}$
0.1	0.0909
0.5	0.333
1.0	0.500
5	0.833
10	0.909
50	0.980
100	0.990
500	0.998
1000	0.999



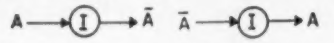
REFRESHER ON SYMBOLIC-LOGIC FUNDAMENTALS



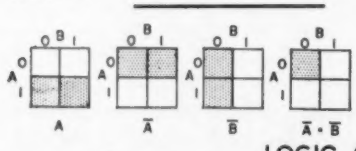
AND gate, symbol, and switch analogy for A AND B = C, written as $A \cdot B = C$.



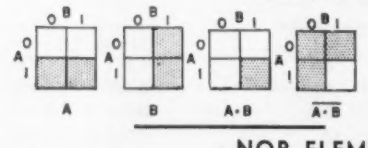
OR gate, symbol, and switch analogy for A OR B = C, written as $A \vee B = C$.



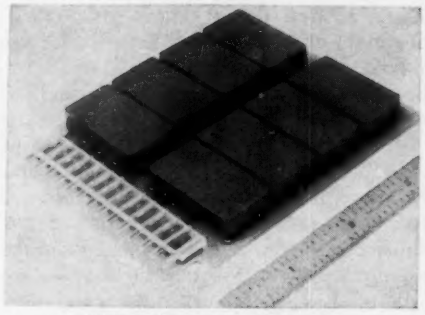
SYMBOL for inverter. $\overline{A}$ means NOT A.



LOGIC CHARTS show truth of statements $\overline{A \cdot B}$ (top) and $\overline{A \cdot B}$ (bottom). They are not the same. Implementation of these expressions also is shown.



NOR ELEMENT has output NOT (A or B). By DeMorgan inversion, this equals $\overline{A} \cdot \overline{B}$.



NOR elements in circuit

NOR ADDITION

ERNEST P. CROZIER, JR.
C & K Components, Inc.

Eight NOR elements can perform binary addition.

A SINGLE TRANSISTOR element (Fig. 1) performs NOR logic (as has been explained previously). It produces an output only when neither one nor the other of its inputs is present. This NOT-OR output is converted into more familiar AND and OR expressions by use of the DeMorgan inversion, as shown in Fig. 2 (and as explained in detail previously).

The action of the element is seen clearly by noting that the output of the NOR element is the same as that of an OR element, but with a NOT sign. That is, if the inputs are A, B, C and D, then the output is $\overline{A \vee B \vee C \vee D}$. By DeMorgan inversion:

$$\overline{A \vee B \vee C \vee D} = \bar{A} \cdot \bar{B} \cdot \bar{C} \cdot \bar{D}$$

If the inputs are $\overline{A}$, $\overline{B}$, $\overline{C}$, the output will be:

$$\overline{\bar{A} \vee \bar{B} \vee \bar{C}} = A \cdot B \cdot C$$

Adder Circuit

Table 1 shows the conditions for addition of binary numbers A and B, where A is one bit, B the other, and C_p a carry from a previous addition.

TABLE I—Symbolic-logic expressions for the sum (S) and carry (C) in adding.

Inputs			Output		S exists when	C exists when
A	B	C_p	S	C		
0	0	0	0	0		
0	0	1	1	0	$\overline{A}\cdot\overline{B}\cdot C_p$	
0	1	0	1	0	$\overline{A}\cdot B\cdot\overline{C_p}$	
1	0	0	1	0	$A\cdot\overline{B}\cdot\overline{C_p}$	
0	1	1	0	1		$\overline{A}\cdot B\cdot C_p$
1	0	1	0	1		$A\cdot\overline{B}\cdot C_p$
1	1	0	0	1		$A\cdot B\cdot\overline{C_p}$
1	1	1	1	1	$A\cdot B\cdot C_p$	$A\cdot B\cdot C_p$

$$S = \overline{A}\cdot\overline{B}\cdot C_p \vee \overline{A}\cdot B\cdot\overline{C_p} \vee A\cdot\overline{B}\cdot\overline{C_p} \vee A\cdot B\cdot C_p$$

$$C = \overline{A}\cdot B\cdot C_p \vee A\cdot B\cdot C_p \vee A\cdot\overline{B}\cdot C_p \vee A\cdot B\cdot\overline{C_p}$$
$$= A\cdot B \vee B\cdot C_p \vee A\cdot C_p$$

There are four conditions for a sum signal—(1) A but not B or C_p, (2) B but not A or C_p, (3) C_p but not A or B, and (4) A, B, and C_p. Similarly, a carry exists only when (1) B and C_p exist, (2) A and C_p exist, (3) A and B exist, and (4) A, B and C_p exist.

The equations in Table 1 are the symbolic-logic expressions for these sum (S) and carry (C) signals.

The second equation for the carry is seen to be equal to the first equation because:

$$A\cdot B\cdot C_p \vee A\cdot B\cdot\overline{C_p} = A\cdot B\cdot(C_p \vee \overline{C_p}) = A\cdot B$$

This is because $(C_p \vee \overline{C_p})$ is the same as 1—that is, A·B exists regardless of the condition of C_p.

Similarly:

$$\overline{A}\cdot B\cdot C_p \vee A\cdot B\cdot C_p = B\cdot C_p\cdot(A \vee \overline{A}) = B\cdot C_p$$

$$A\cdot B\cdot C_p \vee A\cdot\overline{B}\cdot C_p = A\cdot C_p\cdot(\overline{B} \vee B) = A\cdot C_p$$

Fig. 3 shows a circuit using NOR elements to implement the two equations of Table 1.

The inputs to NOR element 8 are the four conditions representing the sum expression. Hence the output of NOR 7 is:

$$\overline{\overline{A}\cdot\overline{B}\cdot C_p \vee \overline{A}\cdot B\cdot\overline{C_p} \vee A\cdot\overline{B}\cdot\overline{C_p} \vee A\cdot B\cdot C_p}$$

By inverting, this top NOT sign is removed and the output of NOR 8 is the desired sum signal.

For the *carry* signal, the output of NOR 6 is:

$$\overline{\overline{B}\cdot\overline{C_p} \vee \overline{A}\cdot\overline{B}\cdot C_p \vee \overline{A}\cdot B\cdot\overline{C_p}}$$
$$= (\overline{\overline{B}\cdot\overline{C_p}})\cdot(\overline{\overline{A}\cdot\overline{B}\cdot C_p})\cdot(\overline{\overline{A}\cdot B\cdot\overline{C_p}})$$
$$= (B \vee C_p)\cdot(A \vee B \vee \overline{C_p})\cdot(A \vee \overline{B} \vee C_p)$$

Multiplying the first and second terms gives

$$(A\cdot B \vee B \vee B\cdot\overline{C_p}) \vee$$
$$(A\cdot C_p \vee B\cdot C_p \vee C_p\cdot\overline{C_p})\cdot(A \vee \overline{B} \vee C_p)$$

Requiring B alone means it is unnecessary to require B AND any other term. Also $C_p\cdot\overline{C_p}$ is impossible and thus equals 0. Thus the equation is simply:

$$= (B \vee A\cdot C_p)\cdot(A \vee \overline{B} \vee C_p)$$

Multiplying:

$$= A\cdot B \vee B\cdot\overline{B} \vee B\cdot C_p \vee A\cdot C_p \vee A\cdot\overline{B}\cdot C_p \vee A\cdot C_p$$

If $A\cdot C_p$ is sufficient, it is unnecessary to require $A\cdot\overline{B}\cdot C_p$. The above expression thus reduces to:

$$= A\cdot B \vee B\cdot C_p \vee A\cdot C_p$$

This is the desired carry signal (output of NOR 6), as shown in Table I.

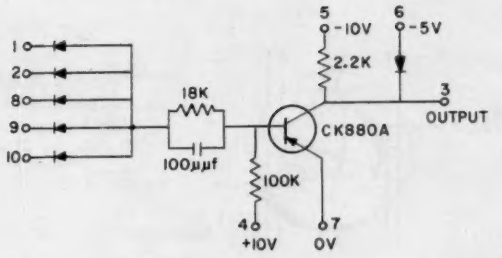


FIG. 1. C & K transistor NOR element.

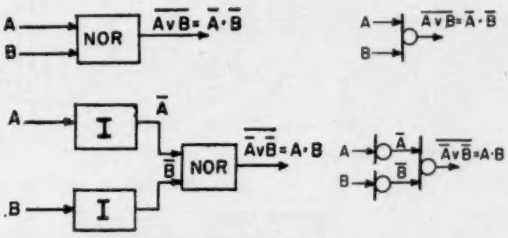


FIG. 2. BASIC NOR element inverts as it performs OR logic. Thus it performs DeMorgan's inversion. Note how the basic logic operations AND and OR are derived from inputs, A, B, $\overline{A}$ and $\overline{B}$. Conventional symbolism is shown at right.

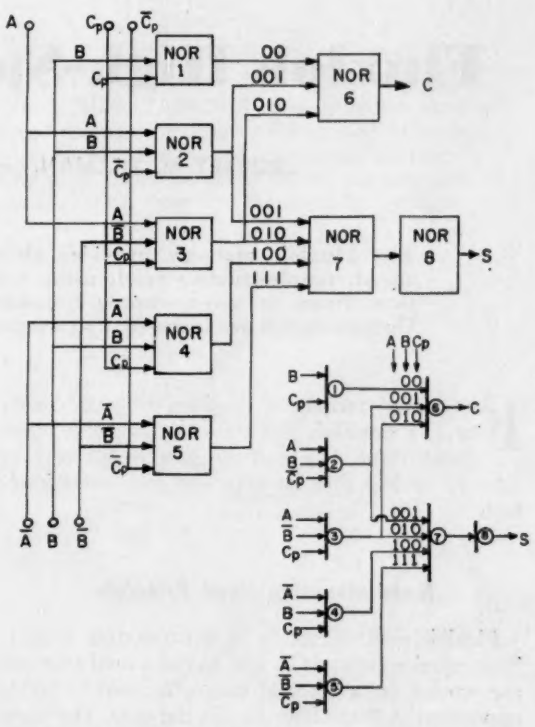


FIG. 3. ADDER circuit using NOR elements. Only 8 elements give the desired outputs for the sum and carry expressions. Conventional symbolism is shown at lower right.

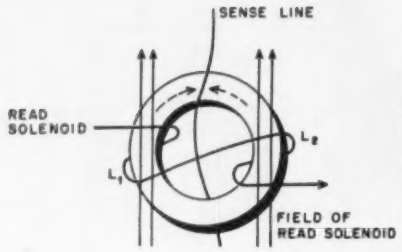


FIG. 1. READ solenoid produces opposing fields in Fluxlok core.

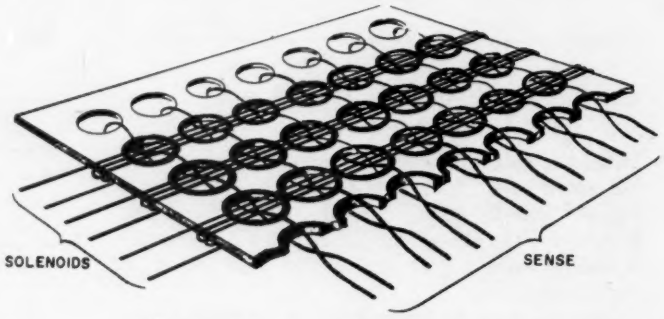


FIG. 3. SEVEN cores (for one 7-bit word) are mounted inside one read-solenoid. Three 7-bit words are shown. Cores fit into holes in phenolic base.

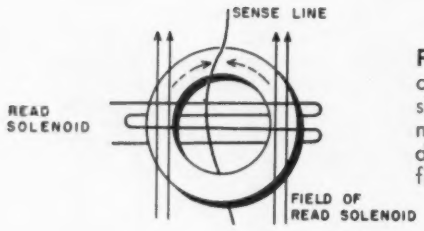


FIG. 2. CORE can be slid inside single solenoid that produces opposing fields.

Fluxlok High-Speed Core Memory

ROBERT M. TILLMAN, Burroughs Corporation Laboratories

The Fluxlok memory provides electrically alterable, random-access, high-speed, nondestructive read, using ferrite cores in a simply wired configuration. Noise or power-supply transients can not change the memory content. Output signals are insensitive to temperature variations from −65°C to +125°C.

FLUXLOK technique employs magnetic fields to (1) establish the state of magnetic cores (write) and (2) read the state of the core at rates to 10 Mc with no apparent core heating effects.

Nondestructive Read Principle

Fluxlok read operation is illustrated in Fig. 1. Two equal windings (L_1 and L_2) of a *read solenoid* are wound on a toroidal magnetic core in series opposition. A *sense line* threads the core. The state of the core can be considered 0 or 1, depending on the direction of the magnetized remanent state of the core (as will be explained in detail). If a current pulse is passed through the opposing read windings, a magnetizing force is produced, but the corresponding circular mmf's in the core cancel one another during the period of the read pulse (as indicated by the dotted arrows), and the remanent state of the core (existing prior to the application of current) remains the same when the read current is removed. Hence the state of the core is not destroyed when it is "interrogated" by a read pulse.

Fig. 2 shows a practical way of placing a single read winding around the outside of a magnetic core so that the mmf from a pulse of current in the winding produces opposing fields, the same effect as in Fig. 1.

The wiring of Fig. 2 is preferred to that of Fig. 1 because of the simple memory plane made possible (Fig. 3). The sense lines can be threaded

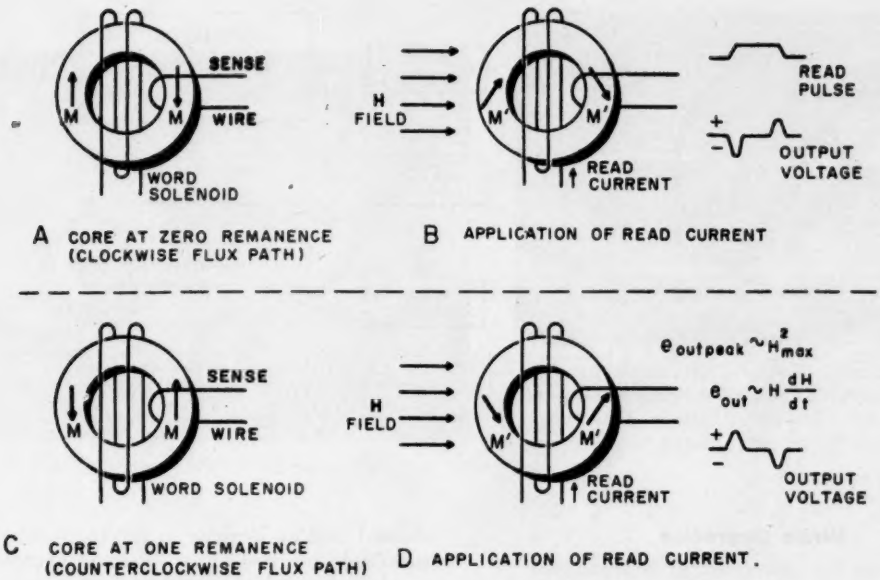


FIG. 4. NONDESTRUCTIVE read operation. M is magnetic moment representing core saturation. Core has 0 state in A, and I state in C. A read current causes an H field. Vector sum of fluxes H and M shows that resultant moment M' is rotated. This causes induced signal (read signal) in the sense wire.

through each core twice, in a transposed fashion as shown, to produce larger output signals and to provide common-mode noise cancellation.

Read Operation

Nondestructive read results from current passed through the read solenoid. Consider a core initially magnetized in the clockwise direction (M in Fig. 4A). Application of the H field (due to current in the read solenoid) causes the magnetic moments M to rotate as shown. The moments now complete their flux paths through air. Creation of air paths by the H field produces a net decrease in the flux within the core, and a voltage of fixed polarity is induced in the linking sense wire.

When the H field is removed, the M vectors snap back to their original position, thereby inducing a second output voltage equal in amplitude but of opposite polarity. With the core originally magnetized in the counter-clockwise direction (Fig. 4C), the H field causes rotation of M in the direction shown in Fig. 4D, and the polarities of the two out voltages are reversed.

The actual sense line (Fig. 1) detects a signal from both sides of the core, rather than from one side (as shown in Fig. 4). The two signals are additive because the sense line crosses the top of one side of the core and the bottom of the other side. Note that one output signal appears on the sense line *during the rise time of the read current*, with a polarity directly corresponding to, and solely dependent on, the state of magnetization of the core (0 or 1). Another output signal equal in amplitude but opposite in polarity, is produced *during the fall time of the read pulse.*

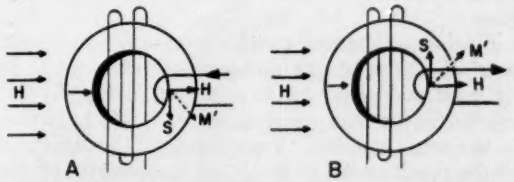


FIG. 5. SIMULTANEOUS currents in the read and sense wire cause moment M' (resultant of H and S) to be in directions shown, depending on polarity of current in sense winding. When currents are removed. M' will relax into the the 0 or I state.

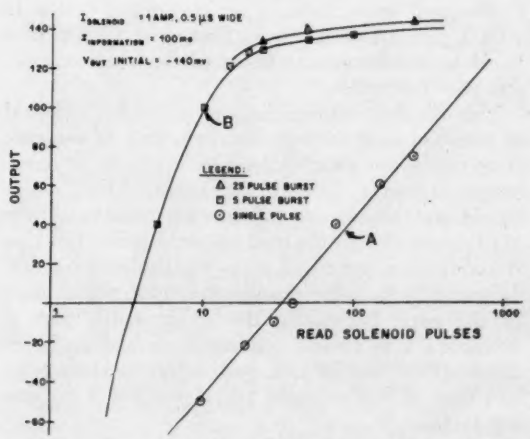


FIG. 6. READ-SIGNAL output (sense signal), in millivolts, versus number of read-solenoid pulses used for write-in. For example, A represent 90 single pulses. B represents ten 5-pulse bursts.

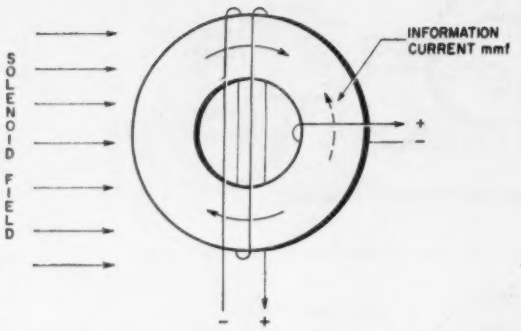


FIG. 7. **WRITE** action for changing core from 0 (CW) to 1 (CCW).

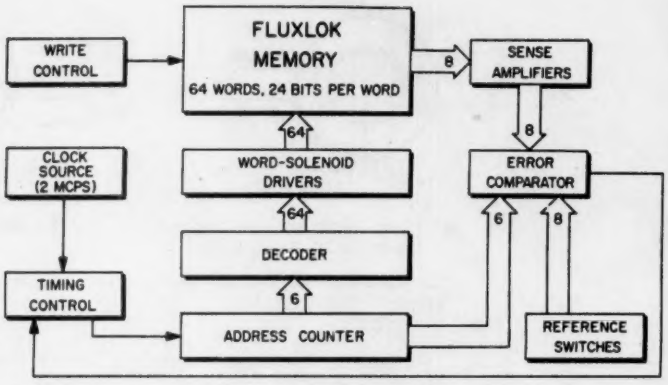


FIG. 8. **FLUXLOK** memory in test circuit.

Write Operation

Write-in can be performed in conventional coincident-current fashion, or by means of a slower but much simpler orthogonal crossed-field technique. In the orthogonal write operation, the same drivers can be used for read or write because these two operations are identical except for the absence or presence of information current in the sense lines.

Fluxlok orthogonal *write* changes the magnetic state of a core by simultaneous use of currents in the read and sense wires, as shown in Fig. 5. The current in the read winding causes field H; current in the sense winding causes field S. The direction of the resultant M′ depends on the polarity of the current in the sense wire. If M′ is as shown in Fig. 5A, it will relax into the S direction (core in 0 state) when the currents are removed. If M′ is in the direction shown in Fig. 5B, the core will relax into the 1 state when the currents are removed.

Where the bits are to remain in their prior 1 or 0 state, the sense current polarity merely drives the core further into its existing remanent state. Orthogonal write, then, is an overriding action in which it is not necessary to first clear all bits of a word to a reference state, as in destructive readout core memories.

This Fluxlok write technique might be expected to result in an extremely fast switching of the core from one given state to the opposite state or remanence. However, investigation revealed that a core would *not* change its information state with the application of a single read-solenoid pulse, but that it required a series of such read-solenoid pulses (about 25) to fully change the information state of the core. Increasing the pulse width from a nominal 0.1 to several microseconds had no beneficial effect. Similarly, it was determined that the rise time of the solenoid pulse was not a governing factor.

Fig. 6 shows the effect of varying the number of read-solenoid pulses for a single write operation, starting, in each case, from a saturated reference state of opposite remanence. Additional tests showed that an increase in the read-solenoid pulse amplitude resulted in an expected decrease in the number of pulses required for full switching of the core.

One theory as to the mechanism by which this slow, ratchet-like write operation takes place is concerned with the differing effects of the pulsed solenoid cross-field on the core magnetic moments in the various segments of the core. In Fig. 7, the cross field opposes the direction of the remanence moments in the lower part of the core, while at the same time this cross field is in a direction to aid the remanence moments in the upper part of the core.

Simply stated, during the presence of a solenoid pulse the flux density in the lower part of the core is decreased by the combined solenoid-field and information-current core mmf, and the flux density in the upper part of the core is changed very little because flux changes in this part of the core are opposed by the mmf produced by the information current.

Upon termination of the pulse field, the core assumes a minimum energy state wherein the two flux densities again become equal. In this case the information current decreases the flux in the upper part and opposes an increase in the flux of the lower part. The result is that the net core flux has been reduced *slightly* towards a demagnetized state. Repeated application of solenoid pulses gradually "walks" the core state through the demagnetized state and eventually to the desired opposite state of saturation.

Test System

In the circuit chosen to test the memory (Fig. 8), the contents of the memory are compared (by means of sequential addressing) with the contents of a binary (address) counter performing the addressing of the memory. In addition, provision was made for setting up a comparison word on a series of reference switches so that any pattern could be entered into any word position and compared during the test cycling of the memory. These patterns

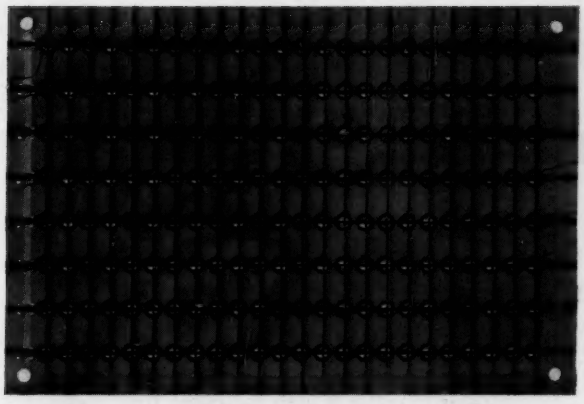


FIG. 9. FLUXLOK memory plane, enlarged.

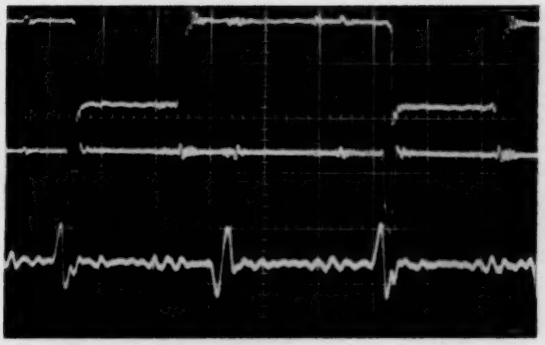


FIG. 10. RELATIVE TIMING of output register (top), sense amplifier (center), and core output (bottom) showing binary 101. Scale of two top graphs is 2 volts/cm; bottom graph scale is 50 mv/cm. Frequency is 1 Mc.

are entered by the orthogonal (crossed field) method of writing.

The memory consisted of eight planes of eight 24-bit words each. Fig. 9 shows one of the memory planes. The storage elements were 50/80-mil ferrite cores. The unit was assembled to simulate a larger memory stack to facilitate studies of noise and crosstalk that might be encountered in a full-sized memory. Additional wires, added in parallel with the word windings for coincident-current write, can be seen in Fig. 9.

A nominal read rate of 2 megacycles (required by the supporting project) was chosen for the test. All circuitry was transistorized except that vacuum-tube drivers were designed to furnish the high-current, fast-rise-time pulses at this frequency. (Reliable solid-state drivers to furnish 1-ampere pulses with 50-nanosecond rise times are limited to about a 500-kc repetition rate with present-day semiconductor devices.) Sense-line signals were fairly clean and uniform, and the sense-amplifier design has proved adequate for the fast-rise-time bipolar output signals.

Fig. 10 is an oscilloscope display of the waveforms taken while reading out binary 101.

Conclusions

The Fluxlok memory technique appears to be promising for those computer applications where its electrical alterability and high-speed nondestructive-read features can be used to advantage. The orthogonal (crossed-field) write feature requires the use of only one diode per word in linear-select memory systems, as opposed to two or even three diodes per word in more conventional designs.

The transition from a laboratory Fluxlok test system to a larger memory system has introduced problems. Proper electrical operation depends on the maintenance of a good orthogonal relationship between the word-windings and the sense wires during packaging. As in any high-speed memory development, the second- and third-order electrical effects become prominent when added together in a large system. A 2048-word 19-bit memory system is under construction. Transistorized drivers and associated memory circuitry have been developed for the operating speeds desired. Circuit capacity and inductance, along with the transistor and diode voltage drops in decoding and selection circuitry created design difficulties. However, the work performed to date indicates that suitable components are now available for this effort, and that the transition from a laboratory test vehicle to a useful, reproducible memory system will be accomplished successfully.

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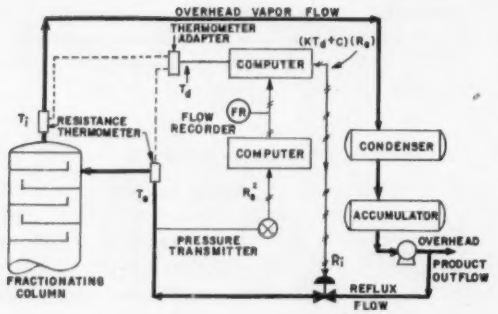
Process Control Systems

INTERNAL REFLUX COMPUTER FOR PETROLEUM FRACTIONATOR



Reflux in fractionating columns requires control to maintain a constant tower top temperature. Cascaded automatic temperature-flow control of the external reflux is the present "conventional" method.

Considerable improvement in the performance of fractionators can be realized by computer control for maintaining constant *internal* reflux flow as a means of overcoming fluctuating *external* reflux temperatures. This method secures a more constant internal reflux, as any correction needed to compensate for a change in differential temperature can be made rapidly by adjusting external reflux flow. Thus process disturbances can be reduced, increased fractionator capacity can be realized, considerable reduction in reboiling steam consumption is achieved and a more uniform composition of valuable products is attained.

Internal reflux is a term computed from measurements of external reflux flow and the temperature difference between the external reflux stream and the top-tray (overhead) vapor together with the specific heat and the heat of vaporization constants for the particular material involved. The internal reflux flow rate (R_i) can be expressed as follows:

$R_i = R_e (c+KT_d)$
R_e = external reflux flow,
T_d = temperature difference between the external reflux stream and the overhead vapor,
K = ratio of specific heat of the external reflux to heat of vaporization of liquid on top tray,
C = constant (usually = 1).

The diagram shows the internal-reflux computer circuit and a column with the reflux circuit.

Equipment required: (2) resistance thermometer units T2E, resistance thermometer adapter T2A, differential pressure transmitter D2T, square root computer C4A/2, AxB computer C4A/2x, modified to provide constant K and C.

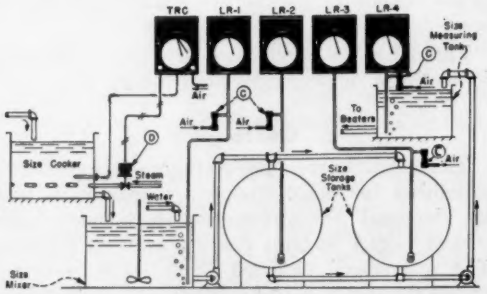
Source: Swartwout Div., Crane Co., Manchester, N. H.

SIZE PREPARATION CONTROLLED BY TEMPERATURE AND "BUBBLER" LEVEL CONTROLLERS

In the preparation of size for use in paper production, starch and other ingredients are boiled in a cooker. Temperature in the cooker has to be maintained at a desired level to prevent boil-over.

A temperature-recording controller (TRC) performs this function automatically by sensing temperature with a pressure filled bulb, and controlling steam admitted to the cooker. Diaphragm control valve (D), the final element, is equipped with a positioner, owing to its size and the necessity for tight shut-off.

Recorders LR-1 through -4 record the levels in the four tanks used in this system, namely the open size-mixer (recorder LR-1), the two vented storage tanks (LR-2 and LR-3), and the open size-measuring tank (LR-4). Measurements are made by the bubbler method; C-clamp rotameters (C) are used for metering the bubbler air. From the measuring tank the preparation is pumped to the beaters.



Equipment used: Pneumatic recording temperature controller, Series 602P1 with proportional action; control valve with positioner; four level recorders, Series 702X; four sets of bubbler accessories.

Source: Minneapolis-Honeywell Regulator Company, Industrial Division, Phila. 44, Pa.; also Bulletin 2801.

LEVEL MEASUREMENT IN CLOSED VESSEL USING PURGE (BUBBLE) TECHNIQUE

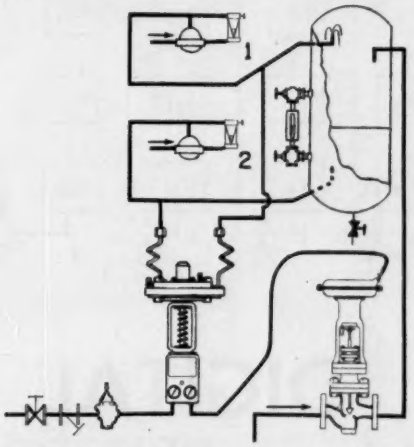
Where level in a closed vessel containing a corrosive liquid of constant specific-gravity is to be measured, a floatless level control pilot can be used to stroke a control valve.

The pilot is a diaphragm-controlled pneumatic relay producing a pneumatic signal proportional to the difference in pressures applied across its diaphragm.

Two "bubbler-type" or purge-type systems are used to produce pneumatic signals proportional to (1) the pressure above the liquid in the tank and (2) pressure at bottom of tank, which is proportional to the liquid level in the tank.

These two signals are used to load the pilot regulator which controls the valve in the line to the tank. The maximum difference of elevation between the variable level in the vessel and the lower end of the fixed reference leg must not exceed the maximum value of the adjustable range.

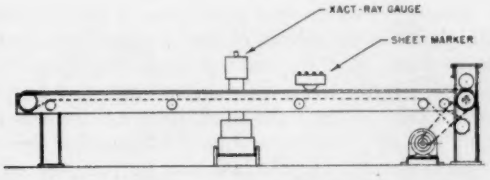
Pilots may be connected direct- or reverse-acting, i.e., an increase in level can cause either an increase in output-signal pressure (direct acting), or decrease in output signal (reverse acting) by reversing impulse connections.



Equipment used: Level-Matic control pilot; control valve; accessories for air supply and purge.

Source: Leslie Company, Lyndhurst, N. J.; also Bulletin LPI-1A-18.

X-RAY SHEET GAGING AND CLASSIFYING SYSTEM



In a typical sheet classifier line, steel sheet is (1) classified in a number of different gage ranges, (2) each piece marked with its gage number, and (3) stacked by gage.

Key to the system (and first stage in this sorting line) is an X-ray gage which monitors the thickness of sheets on the conveyor. Acting as an electronic micrometer, it emits sheet-measurement signals and, through an analysis-control console, also activates roll printers to mark the sheets and sort them into bins.

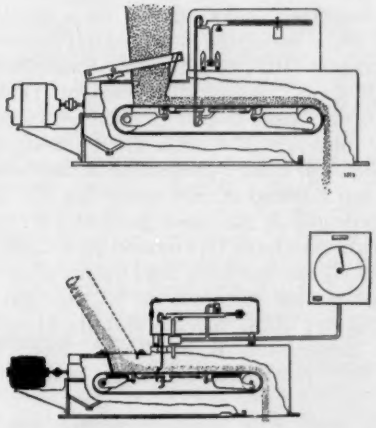
The XactRay gaging system consists of a main console, X-ray source, X-ray pickup unit, and a voltage regulator. In conjunction with this is an automatic classification servo and outside auxiliary equipment.

One XactRay gage can measure down the centerline, or two gages on motorized carriages positioned to left and right over the moving conveyor belt can supply an average thickness reading.

The X-ray classification system is adaptable to a variety of applications. Up to 25 classifications can be made. Categories of material classified, depending on the median thickness, can show tolerance variations finer than $\pm$ 0.0001".

Source: Daystrom Incorporated, Weston Instruments Division, Newark, N. J.

CONTINUOUS AUTOMATIC METERING OF SOLID MATERIALS



Continuous processing of solid materials in flour milling, food processing, ore handling, etc., is a vast field. Mass rate of flow can be measured by a weigh-belt-type Merchen scale meter, combining the weighing section with a sensitive force-balance device which translates rate of flow into proportional air pressure.

As the material passes over weighing platforms, its weight is transmitted to a scale beam. A flapper-and-nozzle relay is operated by variations in the weight of the material above or below the balanced position. A pneumatic recorder records both the rate of flow and totalized flow.

In addition, the Merchen scale meter can be used as a pneumatic proportioning controller.

Source: Wallace & Tiernan Inc., Belleville, N. J.

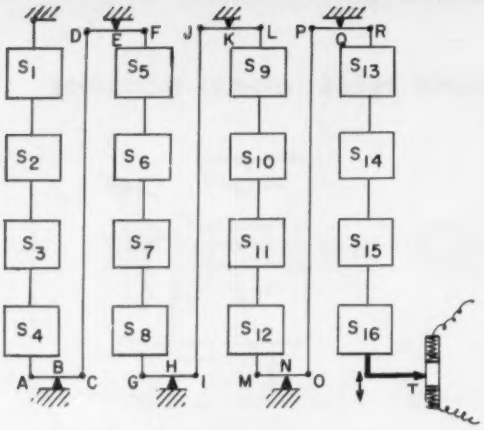


FIG. 1. SIXTEEN linear-stroke solenoids can provide precise, linear positioning in 2^{16} discrete digital increments. Servopositioner with 50″ stroke can be power positioned to better than 0.001″ via binary signals.

T. GIZESKI
Ferguson, Hille & Associates, Inc.

DIGITAL POSITIONING

SIXTEEN SOLENOIDS or cylinders can position to one part in 2^{16} if all solenoids have displacements in binary proportion*—1, 2, 4, 8. The same result can be achieved by using units with only 4 binary-proportioned displacements, and using a mechanical lever to divide the displacement of each cascade of 4 units (Fig. 1).

Solenoids S_{13}, S_{14}, S_{15} and S_{16} are connected directly to the output shaft. Each of these solenoids has a different travel (binary proportion) upon being energized—solenoid S_{13} has a displacement of 0.1″ when energized, solenoid S_{14} has twice this displacement (0.2″), S_{15} has four times (0.4″), and S_{16} eight times this unit displacement. Thus 16 discrete output positions can be obtained from this set of four solenoids. The other three sets of solenoids have identical binary proportioned displacements.

The top solenoid in each group has 0.1″ displacement. Solenoid S_9 can move point M 0.1″. The lever combination reduces this motion by a ratio 16/1, so solenoid, S_9 can move the final output shaft 0.1″/16. This means that solenoids S_9, S_{10}, S_{11} and S_{12} can be duplicates of S_{13}, S_{14}, S_{15} and S_{16}. However, the binary progression is continued. Note that S_{12} moves 0.8″, but moves the output shaft only 0.05″, half of S_{13}.

Each lever pair connecting each set of four solenoids to an adjacent set divides the displacement by 16. The motion of point F is 1/16 that of A. The motion of L is 1/16 that of G. Each group of solenoids thus has 1/16 the influence on final output position as the group to its right. *This is the same as a shift of one place in binary progression.* Solenoids 1-4 represent the first (lowest ordered) four bits or columns (2^0-2^3) of a binary number; solenoids 5-8 represents bits 5-8 (2^4-2^7); etc.

This arrangement permits 2^{16} discrete final output positions, as explained, selected by binary signals.

*Note: Total motion available with 16 binary-proportioned series-cascaded elements is actually $1 + 2 + 4 \ldots\ldots + 32{,}768$ units. This equals $2^0 + 2^1 + 2^2 \ldots\ldots + 2^{15}$, which in turn equals $2^{16} - 1$, or 65,535 units. For practical purposes this can be considered equal to 2^{16}, or 65,536 units.

A point T at the end of the final output shaft can make contact with either of two conducting surfaces, providing a switch-type action. Touching one or the other surface makes a signal that operates a power (hydraulic) cylinder which is used for final actuation, which also repositions the position switch providing closed-loop servo operation.

If a 50″ positioner is used as a final actuator, the theoretical accuracy is $50''/2^{16} = 50''/65{,}536 = 0.00076''$ per bit (of input signal).

Binary-coded decimal positioning is accomplished simply by using only 10 of the 16 possible combinations (that is, 0-9) and by using a linkage that divides by 10. Hence the number 6742 would represent 6 units in the right-hand decade, 7 units in the next decade, 4 in the next, and 2 in the last decade —each number of which would be represented in binary (e.g., $6 = 0110$).

Pure binary position also can be achieved by using a mechanical division ratio of 10—if each solenoid stroke is proportioned properly. For example, if the strokes of the right-hand decade (S_{13}-S_{16}) are set to represent 2^{12} (4,096), 2^{13} (8,192), 2^{14} (16,384) and 2^{15} (32,768), then the strokes of the next decade would have to be set as follows:

$S_1 = 1000 = 2^0 \times 10^3$		$S_9 = 2500 = 2^3 \times 10$	
$S_2 = 2000 = 2^1 \times 10^3$		$S_{10} = 5120 = 2^9 \times 10$	
$S_3 = 4000 = 2^2 \times 10^3$		$S_{11} = 10240 = 2^{10} \times 10$	
$S_4 = 8000 = 2^3 \times 10^3$		$S_{12} = 20480 = 2^{11} \times 10$	
$S_5 = 1600 = 2^4 \times 100$		$S_{13} = 4096 = 2^{12}$	
$S_6 = 3200 = 2^5 \times 100$		$S_{14} = 8192 = 2^{13}$	
$S_7 = 6400 = 2^6 \times 100$		$S_{15} = 10384 = 2^{14}$	
$S_8 = 12800 = 2^7 \times 100$		$S_{16} = 32768 = 2^{15}$	

Note that the range of strokes is from 32,768 to 1000 units, a range of 32.768 to 1, but the total incremental range at the output shaft is 2^{16} (65,536) increments of 1/65,536 each.

Ternary-type (3^n) positioners also are now available in addition to the straight binary types for control of displacement, pressure, force, flow, etc. A ternary unit has three discrete output states. Only seven ternary units are required to provide better than 1 part in 2000 resolution ($3^7 = 2187$.

JOURNAL OF THE SOUTHERN CALIFORNIA METER ASSOCIATION

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Vibration Monitoring

Vibration-induced fatigue is machinery's worst enemy. Destructive force can be indicated only by acceleration-sensitive pickups; displacement alone is a poor criterion.

C. R. CARKEEK
Carkeek Engineering

G. L. CARTER
Robertshaw Fulton Controls Co.

CHARLES R. CARKEEK is president of Carkeek Engineering Co., a manufacturer's representative firm specializing in industrial process and control equipment. Earlier, he was a sales engineer for Taylor Instrument Companies and a research and development engineer for the Texas Company. He has five patents (assigned to the Texas Co.). He is a member of SCMA, AIChE, CNGA, ISA, and other organizations. He authored the paper "Capacitance Level Indicator," Carkeek and Philippi, **Instruments and Control Systems**, Aug. 1959. Chas. has BS in ChE 1943, U of Cincinnati; Reg. ChE, Calif.

GORDON CARTER has been affiliated with Robertshaw-Fulton Controls Co. for the past four years—initially at the company's Fielden Instrument Division, until the Philadelphia facility was merged with the present Aeronautical and Instrument Division in Anaheim, Calif. At Fielden, Carter served in a technical engineering capacity, working closely with the inventor of Vibraswitch. Earlier, he specialized in industrial instrumentation at Sylvania Electric Company's Hatboro, Pa. plant. Prior to this, he served in the U. S. Navy as a communications specialist. He is affiliated with the SCMA and ISA.

AT LEAST 80% of all machine part failures are caused by *fatigue*—fracture of a component subjected to repeated stress. Stress concentrations that exceed a material's endurance limit foster the growth of fatigue cracks.

Usually an increase in vibration is the first sign of incipient trouble. Excess vibration generally stems from causes such as metal fatigue, broken parts, worn bearings and rotors, eccentric loading, misalignment, loose mountings, dirt, and poor lubrication. When mechanical vibration is continuously monitored, abnormal conditions can be detected and damage minimized. Undetected excessive vibration becomes a regenerative, destructive force. It can increase rapidly, causing major damage to machinery and equipment—and danger to personnel.

Vibration Measurement

The most readily understood vibration measurement is the *displacement* of the motion, the amplitude of the motion which a vibrating body exhibits. But measurement of peak-to-peak excursion is insufficient to define vibration's destructive effect.

Damage is due to *force*. Force is at all time equal to the product of mass and acceleration. Hence acceleration is a direct measure of force.

When a body moves in simple harmonic motion:

$$x = x_0 \sin \omega t$$

$$\dot{x} = \omega x_0 \cos \omega t$$

$$\ddot{x} = -\omega^2 x_0 \sin \omega t$$

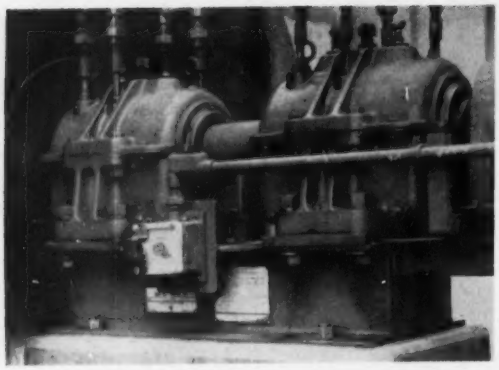


FIG. 1. VIBRASWITCH mounted on base of dual liquid-cooled journals (for driveshaft of turbovane fan) safeguards against sustained abnormal vibration.

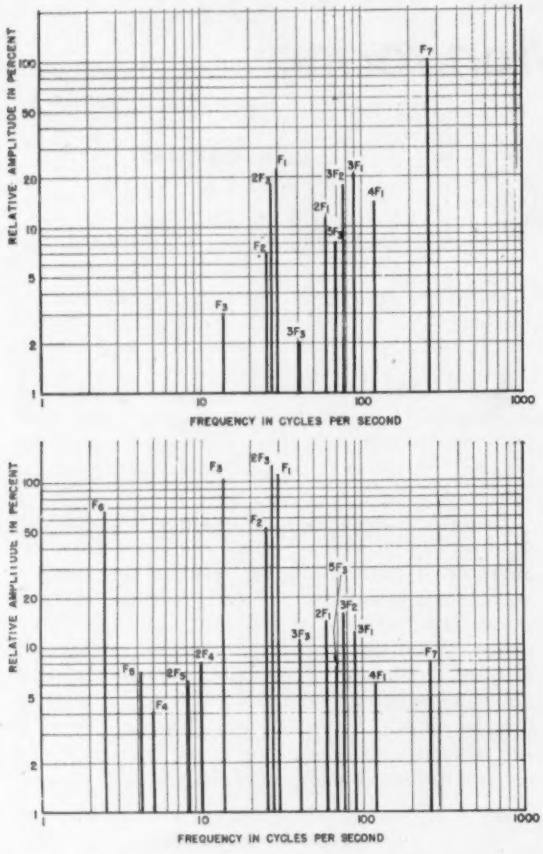

RELATIVE AMPLITUDE IN PERCENT
FREQUENCY IN CYCLES PER SECOND
RELATIVE AMPLITUDE IN PERCENT
FREQUENCY IN CYCLES PER SECOND

FIG. 2. BOTTOM GRAPH shows relative displacement plotted against frequency. Top graph shows relative accelerations of the same vibration at these frequencies. Force is proportional to the acceleration. (Courtesy General Radio Co.)

Meeting Notice—Thur. June 15, 1961. Rio Hondo Country Club, Downey, Calif.
Dinner 6:30 p.m.; Meeting 8:00 p.m.
Subject—Cavitation in Control Valves.
Speaker—Gordon F. Stiles, Fisher Governor Co.
Demonstration—Paul Crowley (B.I.F.) will demonstrate a differential producer and transmitter.

where x is displacement, x_o is maximum displacement, $\dot{x}$ is velocity, $\ddot{x}$ is acceleration, and ω is frequency in radians ($2\pi f$).

The peak acceleration is:

$$\ddot{x} = -\omega^2 x_o$$

Note that the peak acceleration (and hence the force) is proportional to the *first power* of displacement times the *second power* of frequency.

A malfunction can produce a tenfold increase in frequency—and thus a hundredfold increase in force—with scarcely a noticeable increase in displacement. The only foolproof method of monitoring this destructive force, and thus safeguarding machinery, is through use of an *acceleration-sensitive device.*

Displacement vs Acceleration

Fig. 2 compares displacement and acceleration as measurement criteria in monitoring machinery vibration. (A General Radio Vibration Meter 761-A and Vibration Analyzer 762B were used for the analysis.*) The lower bar graph in Fig. 2 shows relative *displacement* for various fundamental and harmonic frequencies. The upper bar graph in Fig. 2 represents relative *acceleration* under identical operating conditions. Note that the relative amplitude of F_2 is 100% in displacement analysis, but only 3% in acceleration. However, the higher-frequency trace, F_7, shows only 8% displacement amplitude, but a relative acceleration of 100%.

Vibration Monitoring Equipment

Many types of displacement-measuring devices exist but few monitor acceleration. Fig. 3 shows an acceleration-sensitive instrument. When acceleration exceeds a preselected level, a magnetic latching mechanism actuates a relay, which can shut down the equipment or sound an alarm. The device can be reset either manually (by pushing the manual reset button) or remotely (by impressing a d-c voltage through a reset coil). A separate time-delay unit can hold the switch inoperative during momentary overloads, normal startup, and other transient disturbances.

This vibration switch (Vibraswitch) is calibrated to measure acceleration in G's (the measured acceleration divided by the acceleration of gravity). Adjustable set-point control permits close-tolerance actuation at any desired value in the 0-4.5-G acceleration range. Frequency response is virtually flat from 0 to 300 cycles per second (18,000 rpm), and uncalibrated accuracy exceeds 5% in this range.

An electronic equivalent of the Vibraswitch would include an acceleration pickup, an amplifier, and a control relay. Yet the switch is no larger than an alarm clock, and has no moving or electronic parts. Only when vibration exceeds the set point does movement occur, and then only one part moves—an armature cantilevered from a flexure pivot.

*Erwin E. Gross, Jr., *Measurement of Vibration*, General Radio Co., p. 29, Fig. 23.

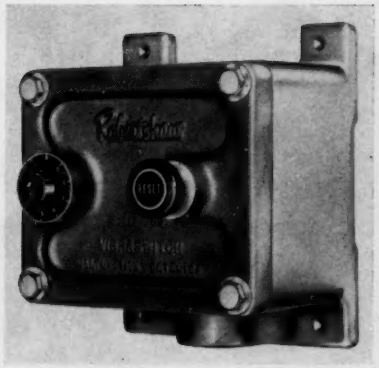


FIG. 3. VIBRASWITCH Model 65 is explosion-proof acceleration-sensitive vibration detector. Contacts close when acceleration exceeds preset level.

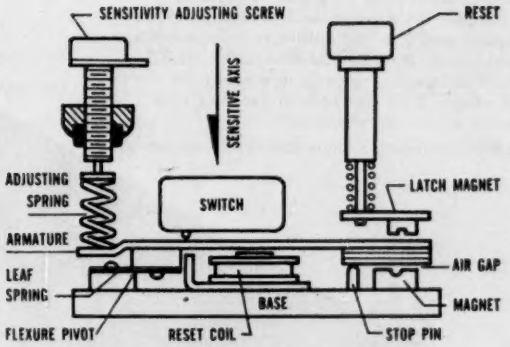
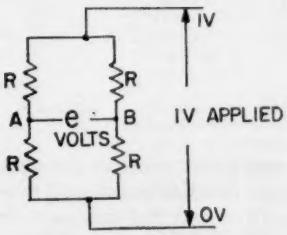


FIG. 4. ELEMENTS of Vibraswitch.

Fig. 4 shows the Vibraswitch elements. It employs a magnetic circuit opposed by inertial and adjustable spring forces in the actuating mechanism. The armature is constrained to only one type of movement by a frictionless flexure pivot composed of two overlapping blocks, and a leaf spring loaded in one direction to hold the block together. The armature rocks on the pivot, being forced in one direction by the adjusting spring and the other direction by the magnet.

When the entire assembly is subjected to vibration perpendicular to the base, the peak acceleration times the effective mass of the armature produces an inertial force aided by the spring, tending to pull the armature from the stop pin and open the air gap. When the peak acceleration exceeds a preselected level, the armature leaves the stop pin, increasing the gap, with the armature continuing to move up until it strikes the latch magnet, actuating the switch during the upward travel. It may be reset by depressing the reset button or applying power to the electrical reset coil.



Strain-Gage Bridge Output

W. E. BOSTWICK, H. C. McDONALD
Lawrence Radiation Lab.

IN a strain gage bridge having equal arms, the output in microvolts per unit strain (microinch/inch) per volt applied = (gage factor)/4. Here is the proof:

$$e = V_A - V_B$$

$$= \left(\frac{R + \Delta R}{2R + \Delta R} \times 1\right) - \left(\frac{R}{2R} \times 1\right)$$

$$= \frac{R + \Delta R}{2R + \Delta R} - \frac{1}{2}$$

$$= \frac{\Delta R}{2\,(2R + \Delta R)}$$

As ΔR is very small with respect to R, we can neglect it:

$$e = \Delta R/4R$$

Thus $\Delta R/R = 4e$

By definition:

$$\text{Gage Factor (GF)} = \frac{\Delta R/R}{\Delta L/L}$$

$$GF = \frac{4e}{\Delta L/L} = \frac{4eL}{\Delta L}$$

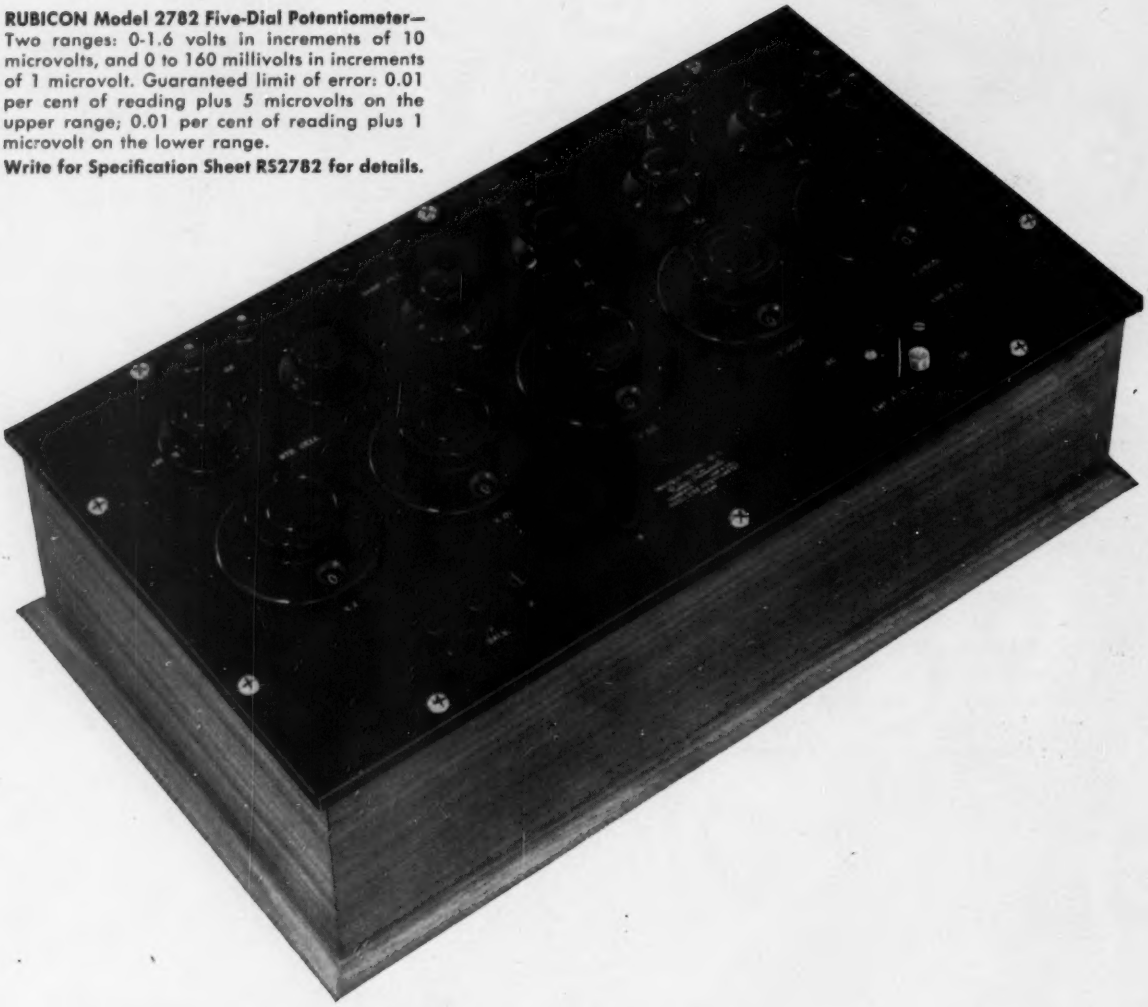
Therefore $e = \frac{GF}{4} \times \frac{\Delta L}{L}$

But $\Delta L/L$ is, by definition, equal to the strain.

Therefore, $e = GF/4$ volts per unit strain per volt applied. Unit strain is expressed as inches/inch. If 10^{-6} inch/inch is used, and e is expressed in microvolts: $e = GF/4$ microvolts per microinch/inch per volt applied.

RUBICON Model 2782 Five-Dial Potentiometer— Two ranges: 0-1.6 volts in increments of 10 microvolts, and 0 to 160 millivolts in increments of 1 microvolt. Guaranteed limit of error: 0.01 per cent of reading plus 5 microvolts on the upper range; 0.01 per cent of reading plus 1 microvolt on the lower range.

Write for Specification Sheet RS2782 for details.



HOW "ACCURATE" SHOULD A POTENTIOMETER BE?

Potentiometer accuracy claims can be misleading. They can sometimes be based on one-shot tests made under ideal laboratory conditions. Their validity can depend on the method used to establish limits of error.

The real measure of potentiometer accuracy is not how little the instrument drifts from set resistance values at one given moment, but how *long* it will remain faithful to its certified calibration. Only a potentiometer that gives consistently stable, reproducible results over its entire life can deliver the performance you pay for.

Such a potentiometer is the one shown above, our Model 2782. It incorporates refinements in potentiometer design that provide high stability and long-term accuracy. For example, the use of high-stability 10-ohm resistors in the first dial and 1-ohm resistors throughout the four lower dials insures permanence of calibration. And because the switch of the first dial carries no current at balance, its contact resistance can introduce no error of measurement. Many other design innovations help maintain the potentiometer's *realistically* high accuracy. Still, the instrument is priced below comparable potentiometers offering far less.

All Rubicon instruments are the product of a long tradition of engineering excellence and exceptional craftsmanship. The complete line is available through any of the Honeywell branches throughout the nation.

MINNEAPOLIS-HONEYWELL, Rubicon Instruments, Ridge Ave. at 35th St., Philadelphia 32, Pa.

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CIRCLE 93 ON READER-SERVICE CARD

Compatibility demands controlled environments, trained personnel, and adequate equipment

WM. B. RICE
Measurement Standards Department
Aerojet-General Corp.

The Semantics of Standards

TABLE 1—DEFINITIONS—WEBSTER VERSUS METROLOGY

	WEBSTER	METROLOGY
Certify	To attest authoritatively; to verify; to endorse authoritatively as being of standard quality.	To state authoritatively the value of a fixed standard, as of a gage block or a resistor, with limits of error involved.
Report	To prepare and issue a formal or official account.	To issue a document comparing readings of an instrument with a standard under controlled conditions and showing the limits of error involved.
Calibrate	To determine, mark or rectify the graduations of, as of a thermometer.	To compare the scales or values of an instrument with a standard in order to determine whether they are within acceptable limits.
Traceable	To be able to show a mark or line left by anything that has passed; a continuous line that can be followed.	To be able to show a record of calibrations against standards leading to the National Bureau of Standards.
Accurate	In exact or careful conformity to truth or to some standard; free from mistake or error.	The degree of conformance to a standard; specifically, the deviation of the observed mean from an assumed true mean.
Precise	Exactly or sharply defined or stated; not vague or equivocal.	The dispersion of observed values repeated under the same conditions at the same time.
Repeatability	To make, do or perform again with the same or different agent.	The dispersion of observed values repeated under different conditions and/or at different times.
Compatibility	Capable of coexisting in harmony; consonant; absence of discord between two things.	Agreement between two or more measurements made with a different traceability to NBS.
Error	An act involving departure from truth or accuracy, a mistake.	Dispersions of observations due to any and all causes; a single or total deviation from a true value.
Accuracy Ratio		The total error at a lower level divided by the total error at a higher level of calibration.

SEMANTICS is the science of meaning, and Metrology is the science of measurements. It is fitting, therefore, to be precise with the words we use, especially as regards *standards*, the current "hot spot" in measurement activities.

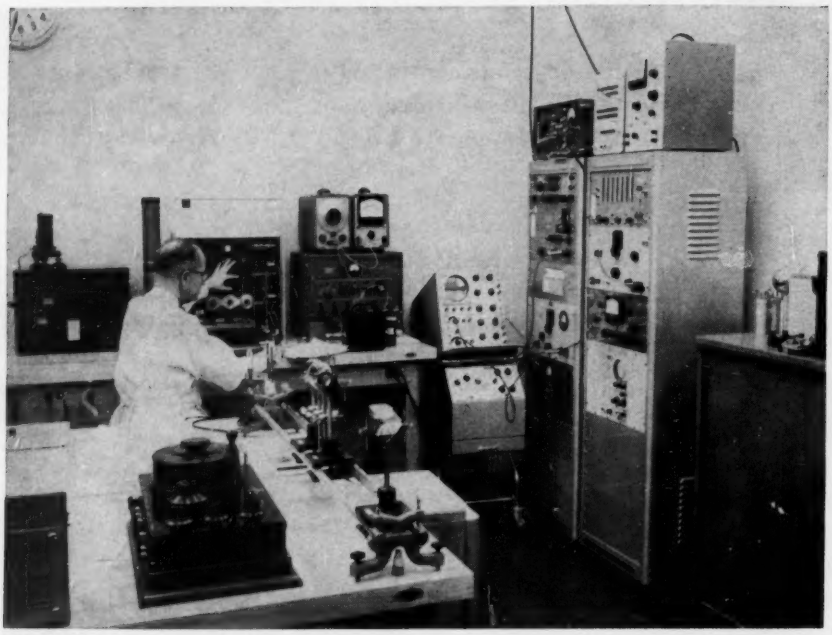
Suppose that I am comparing a secondary gage block, under controlled laboratory conditions, with a standard block certified by the National Bureau of Standards. I record the difference between the two, in millionths of an inch. I repeat the one measurement each day, for seven days; I repeat the measurement seven times consecutively in the space of a few minutes; then I send my secondary standard to another standardizing laboratory where seven consecutive measurements are made. The figures I get are tabulated in Table 2 as deviations from the respective NBS standards.

TABLE 2—TABULATED RESULTS OF MEASUREMENTS

	Precision	Repeatability	Compatibility
	−1	+1	+1
	+1	0	+1
	0	+2	+1
	−1	−1	0
	+2	0	+2
	−1	−3	0
	0	+1	+2
Mean	0	0	+1
Min	−1	−3	0
Max	+2	+2	+2
Range	3	5	2

The first column contains the measurements I made in my laboratory in a minimum time, with conditions changing as little as possible: This is the *precision* of my measurements. The second column contains the measurements made in my laboratory on different days—the *repeatability*. The third column refers to measurements made in another laboratory, where the conditions, the people and the time were all different from mine. I call this *compatibility*.

Now look at the word "error." Popularly, an error means a mistake; in the standards business we try especially hard not to make mistakes, although occasionally we do. Let's admit them, reserving the word "error" as statisticians do, for a "deviation from an expected value." In the latter sense errors can be classified as:



ELECTRICAL plant primary standards laboratory. Aerojet-General Corporation, Azusa, Calif.

(a) those inherent in the equipment
(b) those inherent in the human beings using the equipment
(c) those inherent in the environmental conditions surrounding the equipment and the people.

Looking at the table, we can say, in an ideal sense, that precision minimizes as many of these errors as possible by using the same equipment, people, and environment at the same time. Repeatability means using the same equipment but with changes in environment and people, thus increasing the error. Compatibility implies that equipment, people, and environment may *all* be different, which maximizes the total error.

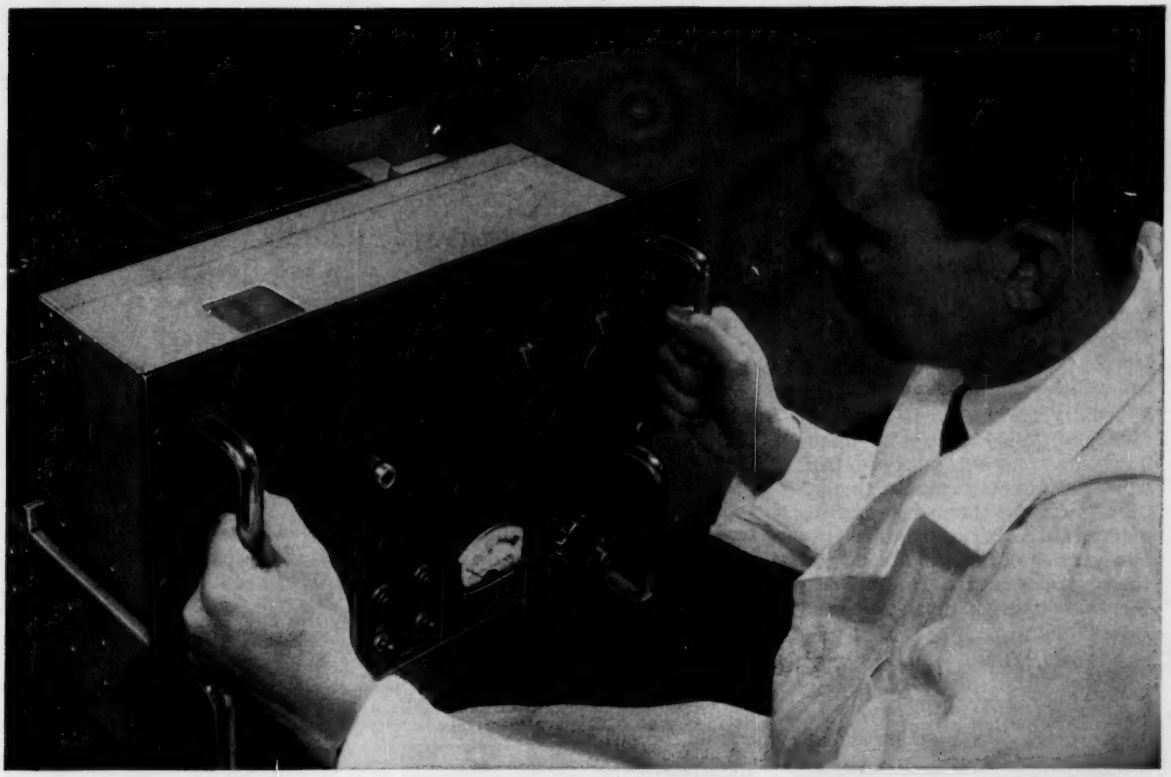
The larger range in Column 2, compared to Column 1, illustrates the added error due to or caused by time —perhaps the temperature and humidity changed throughout the week, or perhaps the people and techniques were somewhat different, or perhaps a bit of dust got caught in a sensitive part of the equipment. The averages or means of both columns being zero indicated, however, that no bias or inaccuracy crept in.

As between columns 1 and 3, the means are not the same, being zero and +1 respectively. There is a bias between columns 1 and 3. Since *my* standards (of course) are directly traceable to N.B.S., *my* technicians are highly trained, and *my* laboratory is the finest, the other laboratory must be wrong. Unfortunately, the range or precision of the other laboratory looks better than mine—is it possible that I am the one who made the mistake? In order to settle this question of whether there really is a difference, it is necessary to make some lengthy statistical calculations. It turns out that the difference between the other fellow's precision and mine is not significant, but the difference between his mean and mine is almost significant at the 5% level. From such calculations I cannot decide whether I am right or wrong—but I can say that the two laboratories are probably not compatible.

Incompatibility can best be adjudicated by a higher authority, and this is the reason why divorce cases clutter the courts of the land. In the standards business, the supreme court is the N.B.S. At this point the meaning and importance of traceability become clear, because if both laboratories have standards traceable to the N.B.S., and if they are re-certified at proper intervals, the probability of incompatibility becomes minimized. Furthermore, incompatibility can be discovered more easily as the precision and repeatability of measurements made in standards laboratories are maximized. *This is why controlled environments, trained people and adequate equipment are necessary in standards work.* Stated statistically, the difference between two means becomes increasingly significant as the dispersions of the samples decrease.

The prevention of incompatibility and the improvement of precision and repeatability in order to facilitate the discovery of inaccuracies is the principal reason for the insistence by the Armed Forces on controlled calibration programs. Any two measurements of length, force, mass, voltage, temperature, etc., must agree within controlled limits of error, and we must have ways to know if they do not agree. Upon this depends the reliability of the weapon systems that we trust for our national security and individual freedom.

Mr. Rice took his B. A. Degree at Davidson College in 1927. He is the author of a book, **Control Charts in Factory Management**, published by John Wiley and Sons in 1947, and has contributed numerous articles to various technical magazines. He has been with the Aerojet-General Corporation since 1956, and is now Head of the Measurement Standards Department, where his major responsibility is the administration of the calibration program at the Azusa Plant.



New Weinschel Plug-in RF Sources for Precision Microwave Measurements provide exceptional amplitude and frequency stability, cover a wide frequency range with true single knob control.

Six new RF Sources, which cover the frequency range of 50 to 10,500 MCS and plug into a common Power Supply-Modulator, have been developed by Weinschel Engineering to meet the demand for stable sources for CW or 100% square-wave modulated RF Power for precise microwave measurements.

For ease of operation, the Power Supply-Modulator, Model MO-3, automatically selects the proper meter range and all the voltages necessary to operate each of the RF Sources without adjustments, thus providing true single knob control. In addition, when a source is plugged into the Power Supply-Modulator, the application of high voltages is automatically delayed until the warm-up of tube filaments is complete.

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Key Specifications are: *(After 30 minutes' warm-up)*

Stability of output power (both CW or Modulated): Better than 1% in 8 hours (for constant load).

Stability of Frequency of 1000 cps Modulator: Better than .01%.

Frequency Stability: 50 to 920 MCS: better than ± .1%. 900 to 10,500 MCS: Better than 1 part in 10^4 in 8 hours, better than 1 part in 10^5 in 15 minutes.

MODEL NO.	FREQUENCY MCS	FOR 50 OHM LOAD	
		MINIMUM POWER OUTPUT, CW	MINIMUM PEAK POWER OUTPUT (100% Square Wave Modulated)
MS-12	50-250	40 MW	40 MW
MS-13	250-920	100 MW	100 MW
MS-8	900-2200	20 MW	20 MW
MS-9	2100-4200	2100-2600 MCS: 30 MW 2600-4200 MCS: 50 MW	2100-2600 MCS: 30 MW 2600-4200 MCS: 50 MW
MS-10	4000-7300	50 MW	50 MW
MS-11	7200-10,500	7200-7400 MCS: 20 MW 7400-9700 MCS: 50 MW 9700-10,500 MCS: 20 MW	7200-7400 MCS: 20 MW 7400-9700 MCS: 50 MW 9700-10,500 MCS: 20 MW

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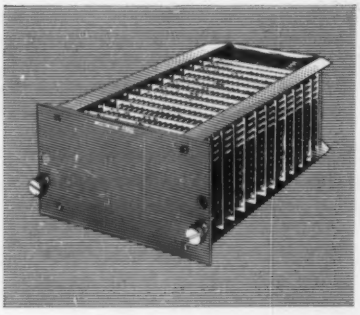
Virtually maintenance-free, the Multiplier 7.036 utilizes a unique quarter-square technique that achieves high static multiplying accuracy without the usual resulting deterioration of frequency response. Diode function generators develop the square quantities from x and y inputs, eliminating the need for internal amplifiers.



Here are the outstanding features of this new multiplier:

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- Static accuracy 0.04%—Zero error 0.01%
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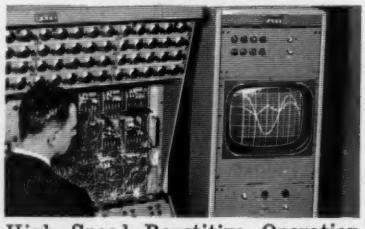
For specific details on the EAI Multiplier 7.036, write to Dept. 27.

SAVE TIME!—WITH HIGH SPEED REPETITIVE OPERATION

Analog computation gains another speed advantage over other computing methods with EAI's new High Speed Repetitive Operation. HSRO users report up to 100 per cent faster results in the solution of many dynamic problems. For the first time, a computer is available that incorporates both high static accuracy and unusually wide bandwidth. The result is a powerful computing combination offering the immense time-saving of HSRO plus the high solution accuracy of "real time" computation. Applications include chemical kinetics studies, control system design, system optimization, mathematical model building, curve fittings, and statistical analysis.



High Speed Repetitive Operation features include:

- Repetition rates of up to 50 cps provide for continuous solution display.
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- Electronically generated display grid—eliminates scope linearity errors and facilitates high readout accuracy.
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For complete details on EAI High Speed Repetitive Operation, write to Department 28.

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AMR	**EETF**
PMR	**EAFB**
EGTR	**NOTS**
WSMR	**WOOMERA**

These are some of the ranges equipped with EAI Range Instrumentation equipment. Since 1946, more than 300 EAI computers, plotters and recorders have been installed on test ranges throughout the world.

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EAI Range Instrumentation is used in the following areas:

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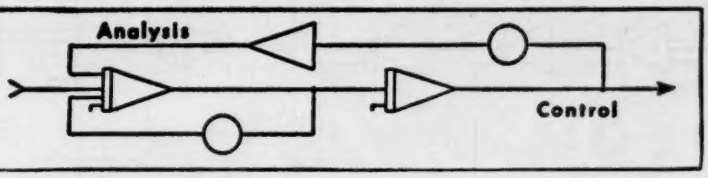

Newsletter

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Bits

This month we have the first of a series of columns on "Analog Techniques and Special Circuits" by **Tom Anderson,** and a rather complete story of the Midwestern Council meeting at the Allison Division of General Motors in Indianapolis last January.

There were five "Featured Papers" at the Allison meeting:

1. "Launching a Small Rocket from a Helical Rail" by **Joseph E. Wilson** (Rock Island Arsenal, Rock Island, Illinois)

2. "Analog Techniques Employed in a 'Half-way-round-the-World' Trajectory Study" by **R. O. Whitaker** (Allison Div., General Motors)

3. "Simulation of Steam Generation in a Heat Exchanger" by **P. J. Hermann** (Iowa State University, Ames)

4. "A Low-cost Time Delay" by **Ralph J. King** (Caterpillar Tractor Co., Peoria, Illinois)

5. "Extended Use of a General-purpose Analog Computer for Missile Control System Development" by **J. E. Westwick** (Allison Div., GM)

These were followed in the afternoon by three "Selected Short Subjects": "Pure Time Delay Approximations" by **John Sansom;** "On-the-fly Rescaling" by **Frank King;** and "Design Optimization by Analog Computers" by **D. W. Sparks.**

SCI Activities, one "He Went" and other ill-assorted information will complete this issue of your *Newsletter.*

INTRODUCING LIMITS TO SECOND-ORDER SYSTEMS

Thomas C. Anderson
Lockheed Missiles and
Space Division
Sunnyvale, California

THERE are several techniques in use for applying position and rate limits to second-order systems which are sometimes applied in a "cookbook" manner without consideration for their effects on system performance. The following discussion is intended to show the effects of some of these techniques and the considerations which should be taken into account in selecting a particular limiting system for a simulation.

In general, each system of limit application defines a distinct nonlinear, second-order system simulation. The various techniques will be applied to the case of a second-order mechanical servo with rate and position feedback and with natural frequency and damping ratio equal to unity. The subsequent action of the simulation will then be interpreted in terms of what type of additional features of the servo are implied by the mechanization.

Position Limits

Figure 1 shows the type of limit sometimes applied in an unsophisticated approach or when working directly from a block diagram. The amplifier in the rate feedback loop is technically redundant, but is included to give continuity for the diagrams. The output δ_o (rotation of the load) is quite distinct from the output of the last integrator δ_s (rotation of the servo shaft). This simulation corresponds to a "clutch with memory." That is, when the limit is reached, δ_o remains at the limiting value while δ_s may go far beyond the limit value. When the command signal δ_c changes sign, δ_s must return from the value at that

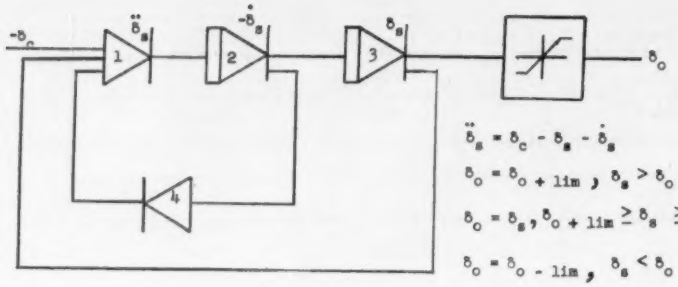

$\ddot{\delta}_s = \delta_c - \delta_s - \dot{\delta}_s$
$\delta_o = \delta_o + \text{lim}$, $\delta_s > \delta_o + \text{lim}$
$\delta_o = \delta_s$, $\delta_o + \text{lim} \geq \delta_s \geq \delta_o - \text{lim}$
$\delta_o = \delta_o - \text{lim}$, $\delta_s < \delta_o - \text{lim}$

FIG. 1

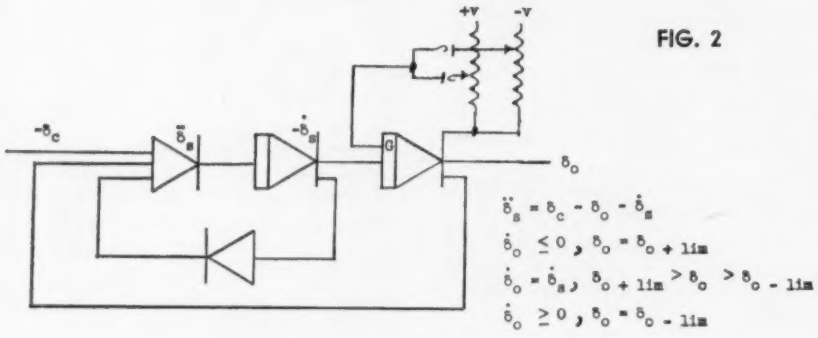

$\ddot{\delta}_s = \delta_c - \delta_o - \dot{\delta}_s$
$\dot{\delta}_o \leq 0$, $\delta_o = \delta_o + \text{lim}$
$\dot{\delta}_o = \dot{\delta}_s$, $\delta_o + \text{lim} > \delta_o > \delta_o - \text{lim}$
$\dot{\delta}_o \geq 0$, $\delta_o = \delta_o - \text{lim}$

FIG. 2

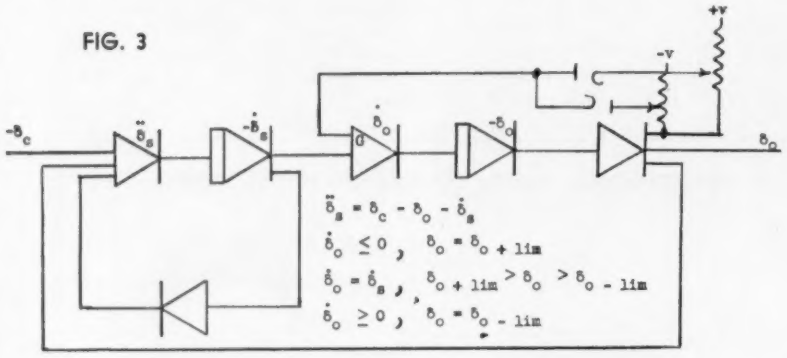

$\ddot{\delta}_s = \delta_c - \delta_o - \dot{\delta}_s$
$\dot{\delta}_o \leq 0$, $\delta_o = \delta_o + \text{lim}$
$\dot{\delta}_o = \dot{\delta}_s$, $\delta_o + \text{lim} > \delta_o > \delta_o - \text{lim}$
$\dot{\delta}_o \geq 0$, $\delta_o = \delta_o - \text{lim}$

FIG. 3

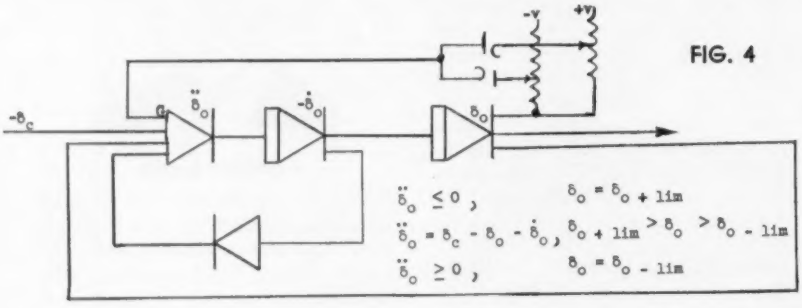

$\ddot{\delta}_o \leq 0$, $\delta_o = \delta_o + \text{lim}$
$\ddot{\delta}_o = \ddot{\delta}_c - \dot{\delta}_o - \dot{\delta}_o$, $\delta_o + \text{lim} > \delta_o > \delta_o - \text{lim}$
$\ddot{\delta}_o \geq 0$, $\delta_o = \delta_o - \text{lim}$

FIG. 4

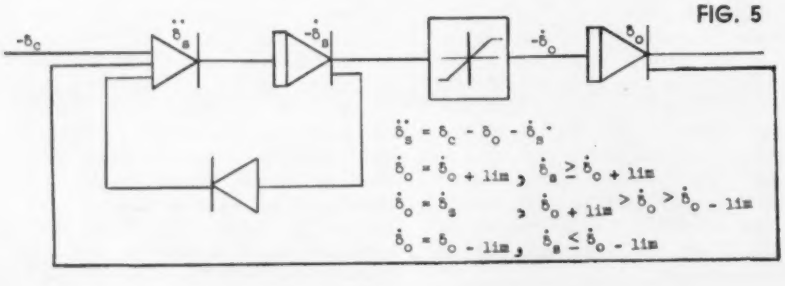

$\ddot{\delta}_s = \delta_c - \delta_o - \dot{\delta}_s$
$\dot{\delta}_o = \dot{\delta}_o + \text{lim}$, $\dot{\delta}_s \geq \dot{\delta}_o + \text{lim}$
$\dot{\delta}_o = \dot{\delta}_s$, $\dot{\delta}_o + \text{lim} > \dot{\delta}_o > \dot{\delta}_o - \text{lim}$
$\dot{\delta}_o = \dot{\delta}_o - \text{lim}$, $\dot{\delta}_s \leq \dot{\delta}_o - \text{lim}$

FIG. 5

time down to the limiting value before δ_o comes out of limit. Thus, the link between the servo motor and the output mechanism "remembers" how far the motor shaft turned past the limit point and requires the motor shaft to perform the same quantity of rotation in the opposite sense before the output can descend below the limiting value. In this type of simulation, the rate of change of δ_o, $\dot{\delta}_o$ is not available since when $\delta_s > \delta_{o\,\text{lim}}$, $\dot{\delta}_o = 0$ but $\dot{\delta}_s$ is not necessarily zero.

In Figure 2, the position limit is inserted as a shunt limiter around the position integrator. The physical mechanism which corresponds to this is a servo motor driving the output shaft through a friction clutch. This simulation permits a rate, $\dot{\delta}_s$, to exist even when δ_o is in the limit. When the command signal changes sign, there will be a finite delay before $\dot{\delta}_s$ changes sign and the output shaft leaves the limiting stop. This corresponds to the effects of the inertia of the servo motor in changing the direction of rotation. Once again, $\dot{\delta}_o$ is not available but if the simulation is modified as shown in Figure 3, both rates $\dot{\delta}_s$ and $\dot{\delta}_o$ are available.

Figure 4 shows the method of applying the position shunt limiter around the entire loop to achieve limiting through control of the acceleration summing amplifier. This corresponds to a system in which the servo shaft is rigidly attached to the output mechanism and the physical stops which produce the limit are rigid and adequate to achieve a rapid deceleration of the servo to zero velocity. In this simulation, all the variables of interest, δ_o, $\dot{\delta}_o$ and $\ddot{\delta}_o$ are present as outputs of the various amplifiers since, in this case, $\delta_s \equiv \delta_o$.

Rate Limits

In Figure 5, a rate limit is produced by placing a limiter in series with the position integrator. This simulates a servo motor driving a heavily viscous damped output mechanism through a friction clutch. When $\dot{\delta}_s > \dot{\delta}_{o\,\text{lim}}$, the clutch is slipping and the output rate will only decrease when δ_s is brought below the limiting velocity of the output shaft. This is a simulation of the inertia lag in reversing the direction of the motor. If the mechanization is modified as is shown in Figure 6, which corresponds to mounting the tachometer on the output shaft, δ_s will be driven even further past limit for a given δ_c time history than in the mechanization of Figure 5.

Figure 7 shows the manner in which to simulate saturation of the motor drive or the rate limit of the motor itself. In this case, as well as in the rigid position limit case, the variables δ_o and δ_s are identical and thus rate and acceleration information are available.

The various types of position and rate limits can be combined to give

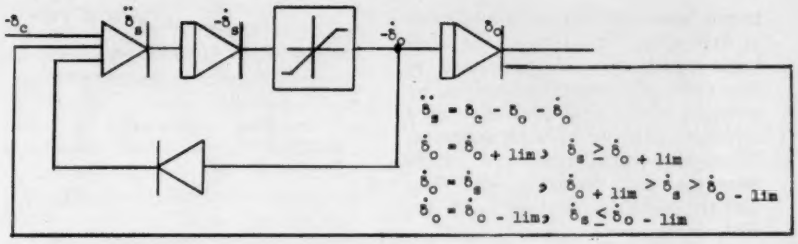

$\ddot{\delta}_s = \delta_c - \delta_o - \dot{\delta}_o$
$\dot{\delta}_o = \dot{\delta}_o + \lim, \ \dot{\delta}_s \geq \dot{\delta}_o + \lim$
$\dot{\delta}_o = \dot{\delta}_s, \ \dot{\delta}_o + \lim > \dot{\delta}_s > \dot{\delta}_o - \lim$
$\dot{\delta}_o = \dot{\delta}_o - \lim, \ \dot{\delta}_s \leq \dot{\delta}_o - \lim$

FIG. 6

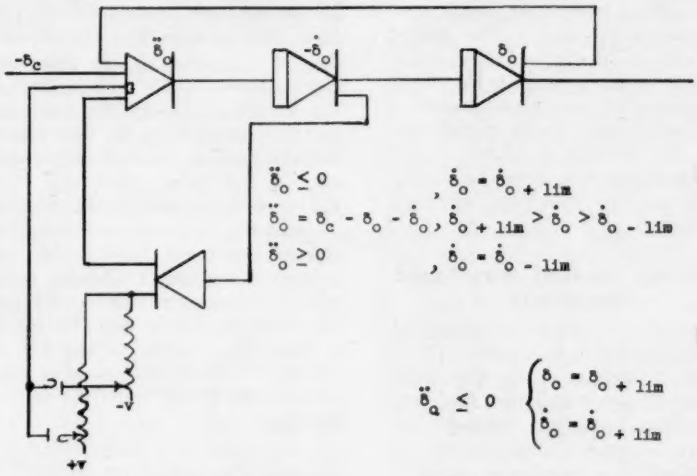
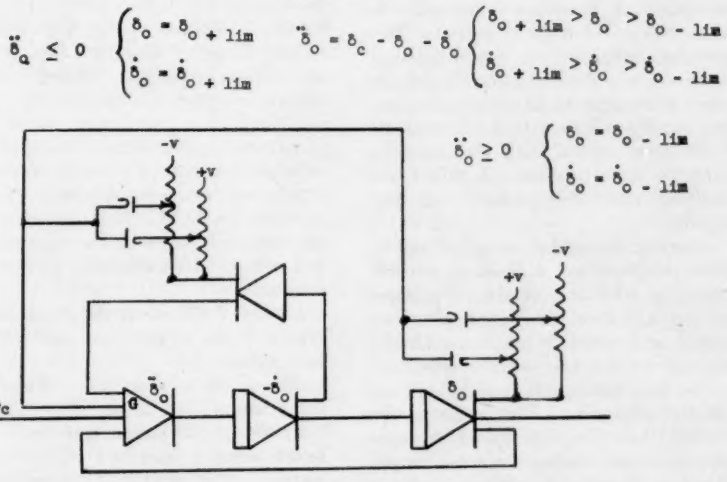

$\ddot{\delta}_o \leq 0$, $\dot{\delta}_o = \dot{\delta}_o + \lim$
$\ddot{\delta}_o = \delta_c - \delta_o - \dot{\delta}_o$, $\dot{\delta}_o + \lim > \dot{\delta}_o > \dot{\delta}_o - \lim$
$\ddot{\delta}_o \geq 0$, $\dot{\delta}_o = \dot{\delta}_o - \lim$

FIG. 7

FIG. 8


$\ddot{\delta}_o \leq 0$ { $\delta_o = \delta_o + \lim$; $\dot{\delta}_o = \dot{\delta}_o + \lim$
$\ddot{\delta}_o = \delta_c - \delta_o - \dot{\delta}_o$ { $\delta_o + \lim > \delta_o > \delta_o - \lim$; $\dot{\delta}_o + \lim > \dot{\delta}_o > \dot{\delta}_o - \lim$
$\ddot{\delta}_o \geq 0$ { $\delta_o = \delta_o - \lim$; $\dot{\delta}_o = \dot{\delta}_o - \lim$
-v
+v
-δ_c

a simulation of both position and rate limited systems. For example, a hydraulic servo might be simulated with rate and position limits as shown in Figure 8.

The systems simulated in Figures 1 and 5 rarely, if ever, occur in practice and are generally of small importance. The system of Figures 2 and 3 occurs in almost all electro-mechanical servos and is quite important. Hydraulic and pneumatic servos are almost invariably of the types mechanized in Figures 4 and 7.

Pieces

MIDWESTERN S/C MEETING OF 16 JAN. ON "NOVEL SOLUTIONS TO NASTY PROBLEMS"

Thanks to **Robert T. Harnett**, Secretary of the Midwestern Simulation Council, we have a complete report on the papers presented at the January 16th meeting of the Midwestern Simulation Council (at Allison Division of General Motors Corporation, Indianapolis, Indiana) on the subject of "Novel Solutions to Nasty Problems."

First Featured Paper of the Day was "Launching a Small Rocket from a Helical Rail" by **J. E. Wilson** of the Rock Island Arsenal (Rock Island, Illinois).

Wilson on Launching Rockets

In the Research and Development Division of Rock Island Arsenal the primary function of the Design Engineering Branch is the design and development of Ordnance Weapons in the field of artillery, rocket launchers, and special support equipment. Since the weapons we design are used ultimately by operational troops, there is constant effort to reduce their weight and complexity of operation.

The problem involved a launching device for a small flare rocket to be used in battlefield illumination.

To evaluate the situation, equations which described the launching loads and motion of the rocket were written by the Theoretical and Applied Mechanics Department of the University of Illinois, under a research contract to the Arsenal.

The generalized equations were a set of six, the first five being algebraic and the sixth a second-order differential equation.

The research contract provided for the solution of these equations on the large digital computer at the University of Illinois—the ILLIAC—for certain parameter variations. We also put it on our analog computer at the Arsenal, the Goodyear A14.

The treatment we chose for the algebraic equations involved a technique we had learned at the Elec-

tronic Associates Computation Center at Princeton, New Jersey. The algebraic equations were converted to first-order differential equations by addition of the first derivative of a different variable to each equation. When the equation reached steady state the first derivative was zero, and the algebraic portion was satisfied.

The outputs of the algebraic equations had to be solved first because the analog computer had to reach steady state to provide initial inputs to the differential equation describing the rotational motion of the rocket. These static values were dependent on the sine and cosine of the angle at which the rocket rested. After the static condition was computed, the lower circuit solving the rotational equation was switched in, and the loop was closed.

To see if our approach to the problem was giving the correct results, we compared the first few solutions with those computed at the University. The greatest deviation we found in any instance was less than 3% and in most cases agreement was much closer, usually within 1 to 1.5% and, in some cases, exact.* This was our first attempt at a problem of this type, and we were well pleased with the results.

During the initial setup period of this problem we did some experimenting with the algebraic portion to get a better "feel" for what we could and couldn't do. Some of the things we learned seem elementary now, but were not apparent to us at the beginning. For instance, we found that the settings of the potentiometers feeding the error amplifiers to be critical, while the adjustment of the potentiometers ahead of the integrators had practically no effect on the accuracy of the results because they contributed only to loop gain. In many instances we found that these pots could have *any* setting without changing the results.

Another thing we learned was that initial-condition voltages can be placed on the integrators and adjusted to keep the error amplifiers from overloading, if a high gain is required and limiters are not used. This, of course, requires that the approximate answers be known beforehand; otherwise it may take a while to find compatible values.

Although this was not a particularly "nasty" problem, it was novel and interesting to us. The algebraic equations were the expected trouble source because their representation on electronic analog equipment implies loops with no integrators, which often gives rise to instability. The method we chose almost always insures stability and seems straight forward, though it does use a great amount of equipment, particularly potentiometers. The method is highly recommended to anyone about to attempt solution of simultaneous algebraic equations.

*These digital computers are sometimes remarkably accurate—Ed.

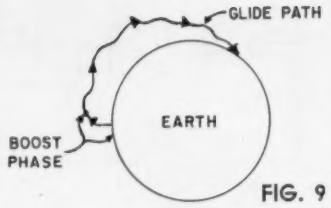


FIG. 9

Whitaker on Half Way-Round the World

The next paper, "Half-way-round-the-World Trajectory Study" by **R. O. Whitaker** of the Allison Division, General Motors Corp. (Indianapolis, Indiana), outlined a systematic method for setting up the equations of a problem to facilitate programming for either an analog or digital computer; for sectioning a problem when the dynamic range of variables of the problem exceeds the dynamic range of the computer; and a method of checking computer results.

Figure 9 shows a diagram of a typical flight of the type used for illustration.

The flight consists of a series of skips about the earth. The vehicle bounces off the atmosphere as if the latter were a stretched rubber diaphragm. The problem naturally divides into two phases—the "boost" phase during which the rocket operates, and the "glide" phase during which the vehicle "glides" to its destination.

The operation of the system in the boost phase is described by a series of equations.

The equations may then be used to set up the computer diagram.

The equations can be used also in setting up a program for a digital computer. This collection of the equations of the problem into a table insures that the problem solved by one type of computer is the same as that solved by the other. The table marks the completion of problem analysis and the beginning of computer programming.

Scaling

Modern analog computers provide high-accuracy computations over a range of about ten-to-one. They provide acceptable accuracy over a range of about 100-to-1. If the dynamic range of a variable in a problem exceeds this range, the computer engineer should break the problem into parts.

In the first section of the problem described, $\bar{u}$ was scaled to 0.25; in the second section it was scaled to 2.5; in the third 25; and in the fourth 100. The missile was "launched," when $\bar{u}$ reached 0.25, the computer was placed on "Hold" and the Boundary Values read out. The computer was then rescaled for the next phase, and the process repeated until burnout.

The work entailed by this method of sectioning of problems is considerable. However, it does enable the computer engineer to handle problems which he otherwise could not. Mr. Whitaker spoke with feeling of a fiasco he remembered too well in which an attempt was made to handle a flight to the moon all in one scaling.

Dynamic Check

A problem solution is accurate if it can be shown that the computation performed by the computer is accurate for all points of the run. A check to see that each computer circuit is accurately performing its appointed calculation *while all variables are changing* is called a "dynamic check."

One way of doing this involves recording all terms of the problem *vs* time. This permits the value of any term calculated by the computer for any point of the run to be read and compared with values calculated from the equations.

Such a comparison is facilitated by preparing a table in which Column 1 identifies the term, Column 2 assigns an identifying number, Column 3 states how the term is obtained (using the identifying number), Column 4 gives the value of the "physical" term so calculated. Column 5 gives the voltage corresponding to this value of the physical term. Column 6 gives the voltage value read from the computer; 5 and 6 then give a check of the accuracy of the machine computation.

To determine the accuracy of the machine computation at any other point of the run, the Boundary Values are read out from the recordings and used to calculate the Process Terms. The values so determined are compared with values from the recordings. This process may be repeated for as many points

of the run as desired. For a quick check only the "dot" terms need be compared.

The foregoing check does not include operation of the integrators. They may be checked by reading the slope of the curve of the Boundary Value Term and comparing this value with the value of the "dot" term. This works very satisfactorily except for the initial point of the trace. If the variable is changing rapidly, the initial slope is most difficult to "guess." To check this point accurately, inverters may be placed ahead of the integrators and the problem run "backwards in time." In the practical setup the problem is run forward from the initial point for a short distance, the inverters inserted, and the problem then run backwards. This gives a continuous trace through the initial point and permits the slope to be "guessed" with as much accuracy as any other point of the run.

P. J. Hermann on Heat Exchangers

The third paper, "Simulation of Steam Generation in a Heat Exchanger," was by our long-time friend and hard-working Simulation Council member, **P. J. Hermann** (Department of Aerospace Engineering, Iowa State University, Ames, Iowa). However, as he himself says, "The procedure is not new and has been discussed broadly in the literature." Here we would like to state the problem—in case you have one like it—then jump to P. J.'s conclusions.*

The problem in simulation considered concerned simulation of steam generation in a large boiler or heat exchanger. Such a problem is of interest because of the number of interacting factors involved in the steam generation process. The rate of flow of heat into the primary or "hot side" is often a variable independent of the heat-exchanger action. The rate of heat transfer from the primary to the secondary depends upon changing temperature gradients and fouling factors. The rate at which the secondary fluid absorbs heat from the primary depends upon the state of the secondary fluid: is it liquid, vapor, or boiling? The boiling point of the secondary fluid depends upon the secondary pressure. The pressure depends upon the rate of generation of steam, and the rate at which steam is drawn off. Temperature of the secondary liquid depends upon pressure, rate of heat transfer, rate of flow of injection water, and temperature of injection water. All of these factors are inter-related with varying degrees of complexity. The simulation problem is to reduce the complete process to a block diagram, or flow chart, that will lead to a simulation on an analog computer. The simulation should be sufficiently accurate to represent the system for both dynamic and static operation but it should not be so detailed that it becomes unwieldy and unreliable.

The simulation technique described was the brain-child of **L. P. Slivka** (new with Hughes Aircraft Co.), with certain corroborative analysis by P. J. while both were with Goodyear Aircraft Corporation in the Dynamic Systems and Computation Laboratory. The particular simulation for which this technique was developed involved a steam-generation heat exchanger.

Fluid in the primary system carries heat at high temperature into the exchanger, loses heat to the cooler secondary water and exits at a lower temperature. Heat transferred to the secondary raises the temperature and causes boiling and steam generation after the water boiling point has been reached.

Steam collects in the steam cavity and, unless drawn off, increases the pressure in the cavity. As a result, the boiling temperature of the secondary is increased and additional heat must be absorbed by the unvaporized water before boiling can again take place. As the pressure is increased the steam in the cavity is compressed slightly and its temperature is increased so that it is slightly superheated. Consequently, some of the steam at the surface is condensed, the pressure is reduced, and the steam regains a saturated state.

Equilibrium conditions seldom exist in a practical installation, so that none of the temperatures, pressures, or flows are constant.

The rate of heat transfer from the primary to the secondary is not constant along the length of the tubing that carries the heat-carrying fluid in the exchanger. This is true since heat flow is essentially proportional to the temperature difference across the heat transfer boundary, and this temperature difference becomes smaller as the primary fluid loses heat. The temperature of the secondary side is essentially constant throughout the boiler because of high heat conductivity and convective mixing. Thus, it is seen that the rate of heat transfer is both time and position-dependent and is described by a partial differential equation. The heat-transfer coefficient is in general not constant. It is usually dependent upon temperature and the degree of fouling of the heat transfer surfaces and, in addition, to the thickness, turbulence, and properties of the vapor film on the secondary surface of the tubes. Thus, in general, the partial differential equation is nonlinear.

Simulation of the heat-transfer process is itself a "sticky problem" requiring considerable additional study to perfect. It can, however, be simplified and approximated with sufficient adequacy to support the needs of system simulation studies in which the heat exchanger is only one of a number of major components. To simulate a process described by a partial differential equation it is necessary to consider the process as a series of "lumped parts" each described by an ordinary differential equation. This procedure is equivalent to the numerical process of breaking the partial differential equation into a set of n ordinary differential equations by utilizing finite differences of one or more of the independent variables.

After thus stating the problem, P. J. goes into four pages of prose and math, and concludes that the technique involves a considerable amount of nonlinear equipment and a number of simplifying assumptions. It is capable of providing good simulation characteristics over a broad range of pressures.

The particular purpose of this simulation was to obtain simulated steam pressure as a dynamic function of heat flow rates, injection water rate and temperature, and steam flow

*Those interested can get the details by writing to P. J.

PAUL J. HERMANN has MS degree in Theoretical and Applied Mechanics, Iowa State University. From 1947-1950 he was instructor at Iowa State. From 1950-1960 he was with Goodyear Aircraft Corp., Akron, working on computer applications, analytical dynamics, nuclear reactor heat systems, etc. He is now at Iowa State University. P. J. is 37, has two children. He is a senior member of IRE, and belongs also to IAS and Midwestern S/C, of which he is now chairman of the Steering Committee.

rate from the boiler. P. J. said he felt, however, that many of the basic ideas might be applicable to studies of systems with quite different characteristics.

King on Time Delay

The fourth featured paper of the morning was "A Low-Cost Time Delay" by **Ralph J. King** (Caterpillar Tractor Company, Peoria, Illinois).

In certain systems which are to be simulated there may occur a phenomenon which it is desired to reproduce in its undistorted form at a given interval of time later. Such a phenomenon is called a *transport lag*. (A familiar example is a shower bath with a manually controlled temperature valve.)

The creation of a time delay (or a *transport lag*, as it is correctly termed) can be done on electronic analog computers by using auxiliary equipment, or by using the computer components to build time delay by simulating a mathematical equation describing the function. Two types of auxiliary time-delay devices are (1) the **magnetic tape transport,** where a function can be written on the tape and read off a fine time later, and (2) a device similar in concept, reported at a Simulation Council meeting a while back—a **rotating wheel with capacitors** which are charged and read at a later time. One mathematical equation, the simulation of which leads to a method of creating a time delay using the normal computer hardware, is the Padé Approximation.

Ralph's group at Caterpillar wanted to simulate a diesel engine cooling system having two "delays"; one at the thermostat, because it requires a finite amount of time for the thermostat opening to reflect a given temperature; the other a transport delay reflecting the amount of time it takes for a unit volume of water to reach the thermostat from the pump.

The first method used to get a transport lag was to simulate the true time-delay function, $e^{-s\tau}$ using the Padé Approximation (which Johnson explains in *Analog Computer Techniques, pages* 127-132).

Ralph explained that they did not have success with the Padé Approximation; the input into the transport delay was not a pure sine wave.

Then a simple apparatus was conceived by **W. H. Belke.** It consists simply of a means of duplicating the input voltage by manually tracking an oscillograph trace with a pointer which also drives a potentiometer, and hence recreates the desired function. The amount of time delay, of course, depends on the position of the pointer with respect to the oscillograph pen and the speed of the paper.

"We were surprised," Ralph said, "At the accuracy with which the technician operating the control knob could follow the input function with the pointer."

An advantage of this time lag apparatus is that it is possible to vary the amount of time lag as a function of some other variable in the problem. Such a variation was desirable in the example because the transport lag between the water pump and thermostat depends on engine speed. A simulation of this variation in the delay was accomplished by having a second technician move the board back and forth on the oscilloscope frame as engine speed varied. This was facilitated by having a fixed wire angled at 45° on the board which was kept lined up with the point of the pen drawing the engine speed trace. Again, this was accomplished with more precision than one would have guessed possible.

"While the device is anything but a finished piece of computer hardware," Ralph concluded, "If you ever need a quick method of creating a transportation lag, you may find this a useful way of doing it."

Following the presentation, **John Sansom** (Wright Air Development Center, Ohio) said, "I was wondering what frequencies you were trying to delay and how much you were trying to delay them?"

Ralph replied, "I believe the second-order Padé Approximation is linear to only 2-3 cps. The fourth will go up a little beyond that. But this is for the fundamental, and I think one of the things that we did not consider fully at first was the high-frequency content of these complex waves. You can easily get distortion that will be meaningful to you in a sawtooth wave such as we had."

This caused **Vince Rideout** (University of Wisconsin, Madison) to volunteer: "One simple scheme to clean up the Padé is to add a single lag to it. Use a second-order Padé and take three-quarters of the delay there and one quarter in a simple lag. Of course this isn't time-variant. The trouble with the Padé is that it's flat in amplitude for all frequencies, and no matter how good the phase is, sooner or later it drops off and those frequencies come through and wreck you. A simple lag will take them out.

The remarks about how well a human could follow a trace moved Mr. Whitaker to comment, "I have used such a 'bio-mechanical' link in putting arbitrary inputs into a computer, and found that it works out very well."

Westwick on Missile Control

The final featured paper of the morning session was "Extended Use of a General-Purpose Analog Computer for Missile Control System Development" by **J. E. Westwick** (Allison Division, General Motors.)

Analog-computer simulation of missile-control systems is not unusual in development programs, due to the ease with which design and performance information can be obtained. Control components are selected based on the results of analog studies, and are tested for reliability and performance characteristics. The final control package is designed, fabricated, and tested—then used.

However, errors due to the inability to simulate accurately all the control-hardware characteristics sometimes make necessary a return to the computer simulation, and possibly a new control package fabrication. Mr. Westwick's paper advocated an extended use of the analog computer to minimize such unforeseen errors and thereby cut development time and fabrication costs. Furthermore, if the control system is to be "breadboarded" but not packaged for missile use, an additional use of the computer is recommended.

By conventional simulation studies on the analog computer, motor and gear ratio requirements were determined, considering gear backlash, motor inertia, motor friction, gearbox friction, and vernier-control rocket-reflected inertia effects. Since the vernier rocket inertia changed as the rockets burned out, the change in total vehicle inertia was considered along with wide variations in vernier rocket thrust available.

Next the motors and gears were obtained which most nearly fitted the requirements; it was felt that proceeding to a finished control system was not feasible until an intermediate hardware-simulation was undertaken.

It was found that the actual motor and gearbox characteristics were different from the values used in the

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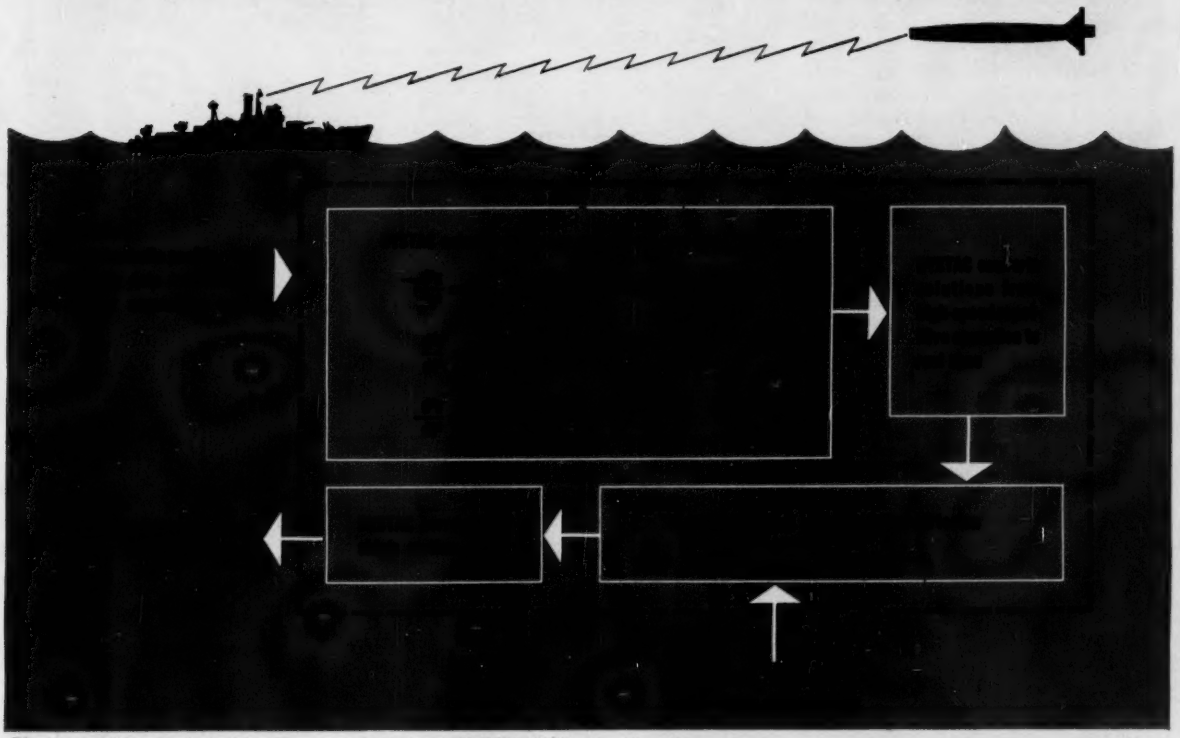

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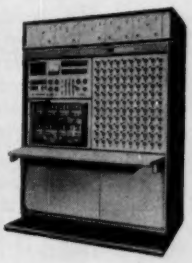

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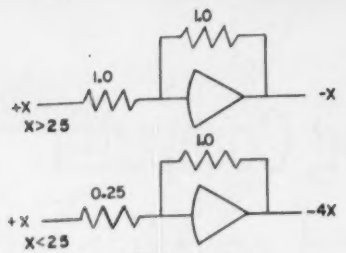


FIG. 10

computer study, and corrections were needed in the control-loop feedback setting. When the control loop with real hardware was optimized, only actual control of the vehicle dynamics remained untested. The advantage of this step is that no control electronics fabrication is necessary because the computer simulates this portion of the system. Another advantage is that unlimited runs and fixes can be taken on the hardware to get optimum performance with no more cost than the manhours involved.

This third phase of control system development, in which a fixture was built to simulate the missile characteristics, and was controlled by the breadboard electronics and analog computer, was made easier because of the work done in the hardware-computer simulation study. The use of the analog computer in this last phase also eliminates the expense of building and testing the control electronics, because this is left as it was for the computer simulation—*on the computer.*

This development program proved that extending the use of an analog computer beyond the initial simulation study to hardware-computer simulation tests and static firing tests cuts development time and fabrication costs by a large percentage over all other possible techniques.

Sansom on Delay Approximations

The afternoon session of the Midwestern Simulation Council meeting at Allison began with the first of the "Selected Short Subjects": "Pure Time Delay Approximations" by **John Sansom** (Wright Air Development Division, Wright-Patterson Air Force Base, Ohio).

Though this paper was of considerable merit and treated a subject of unquestioned importance, the problem of simulating time delays will not be rehashed here because of the amount of attention the subject has received in the *Newsletter* heretofore, and because of the thorough treatments available in the literature.

We should add, however, that the author presents an interesting comparison of errors due to the Padé and other approximations which might make it well worth an interested reader's time to write for a copy of the paper.*

However, the following comments which Sansom's talk elicited are not available elsewhere:

Vincent Rideout: "A comment regarding the response of this scheme. If you take a sinusoid and vary the time delay sinusoidally, you will find that there is an amplitude modulation that appears. Depending on whether you are increasing or decreasing the time delay, you will get an increasing or decreasing amplitude response."

Vern Larrowe: "If you wanted a longer time delay, would you build a higher-order delay or cascade two lower-order ones?"

John Sansom: "I would say to cascade because I know that the sixth order is not necessarily better than the fourth-order approximation, certainly at low frequencies."

Larrowe: "We tried it once with an eighth-order delay and it generated signals with nothing going in!"

Sansom: "We had similar troubles when the method shown in the report for the Pade approximation was used. If the delays are long enough, and the frequencies are low enough, you can get by with only one approximation circuit. We put a 0.1 rad/sec. signal through an 80 second delay and the measured errors were as predicted."

P. J. Hermann to Ralph King: "At Caterpillar Tractor, was the equipment limitation the main thing that kept you from using the time delay approximations discussed here?"

Ralph: "For the second- and fourth-order approximations, we had plenty of equipment, but this was not giving us the results we wanted and the distortion was causing trouble. We saw no point in pursuing a path that wasn't leading anywhere. But we had not investigated it to the extent that John Sansom has."

*John Sansom (WCL-JES), Wright Air Development Center, Analog Computer Div., Wright-Patterson Air Force Base, Ohio.

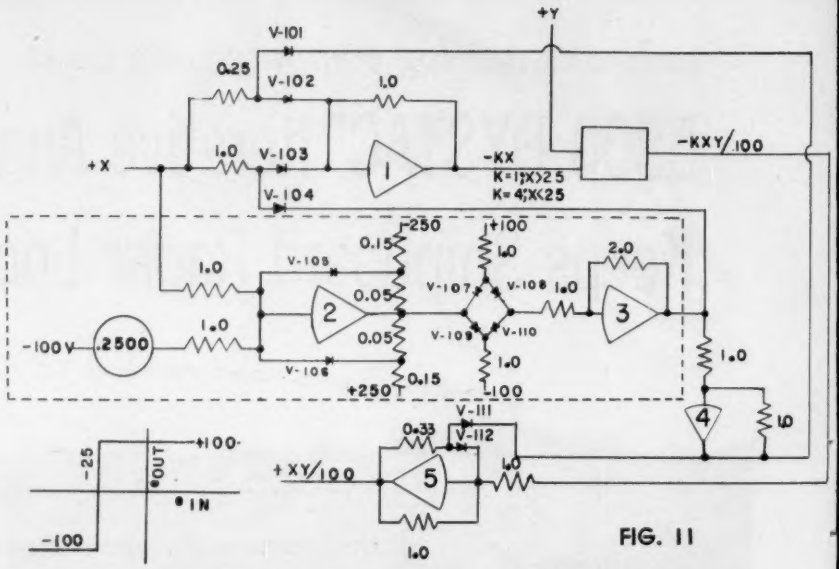


FIG. 11

King on "On-The-Fly" Scaling

The second "Selected Short"—"On-the-Fly Rescaling" by **Frank King** (Allison Div., GM), seemed especially selected to complement the second featured paper, which made a case for rescaling but pointed up the labor involved.

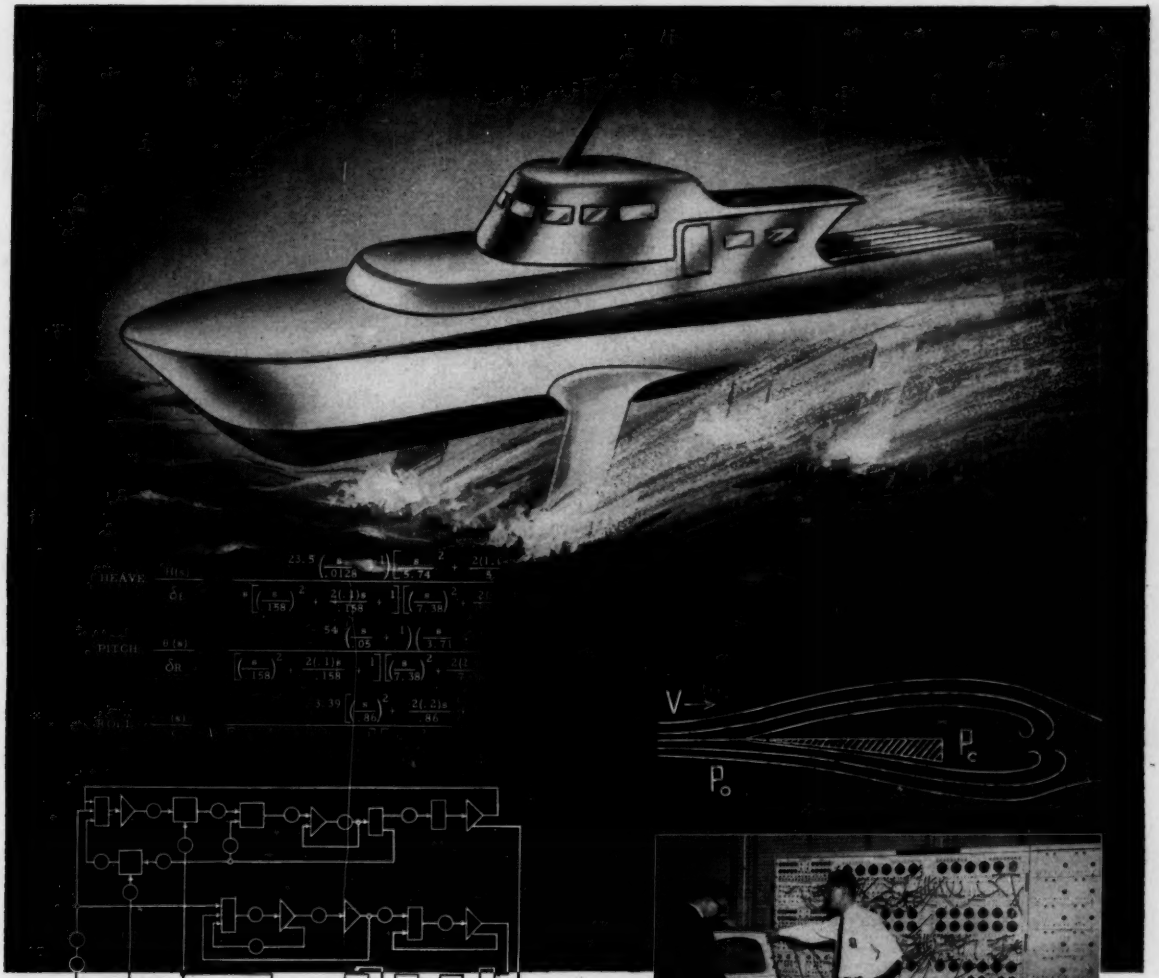
One solution to this problem, said Frank, is to perform "on the fly" rescaling. In order to demonstrate the principles involved in this method the following problem has been formulated:

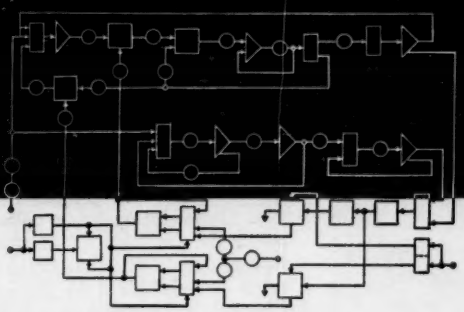
Given a quantity x, which varies from 0 volts to 100 volts, assume that it is desirable to feed this value of x through an inverter such that when the value of x is greater than 25 volts there is a one-to-one multiplication factor through the inverter, and when the value of x is less than 25 volts there is a four-to-one multiplication factor through the inverter (Figure 10). Thus, the problem becomes one of combining the illustrated two circuits electronically and thus avoiding mechanical methods such as relays, which have a finite switching time.

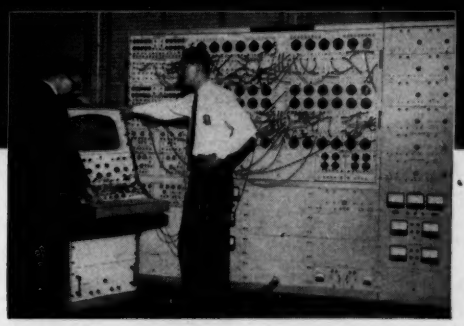
The method used to accomplish this rescaling combines two principles, the flip-flop circuit and the diode switch.

The flip-flop circuit is one which was described in detail in *Electronics*, Nov. 6, 1959, by H. Koerner & A. G. Korn. This circuit is shown in the dotted lines in Figure 11, along with its input-output function.

As shown in Figure 11, the output of this circuit is then used to drive one of the diodes (V-101 or V-104) in the diode switch to conduct; and diodes either V-102 or V-103 will conduct depending on the size of the x input. This provides that the output of amplifier 1 will be $+KX$ where $K = 4$, $X < 25$; $K = 1$, $X > 25$.







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The scale factor is removed from the problem by another diode switch in the feedback around amplifier 5.

In this problem the rescaling was done to raise one of the inputs to a multiplier; however, this method can be used also for rescaling other devices, such as function generators.

The presentation brought forth the following comments:

Westwick: "Did you try relays?"

King: "They were too slow."

Sansom: "What about the step that is inserted in the problem when you make this change in scaling?"

King: "All we're doing is rescaling across the multiplier so no step appears in the problem."

"These were electronic multipliers you were using, right?"

"Yes."

Larrowe: "What kind of diodes did you use and what trouble did you have with their back resistance?"

"We used IN 464's, a Sylvania diode, and the back resistance did not bother us. We tried to eliminate it by putting a diode in the feedback around the amplifier so that we had a diode in the input and an equivalent resistance in the feedback and we seemed to have some success there."

Sparks on Design Optimization

The last "Selected Short" and final presentation of the day (and the "Pieces" part of this lo-o-ong *Newsletter*) was "Design Optimization by Analog Computer" by **D. W. Sparks** (Tammen and Denison Computing Center, Chicago, Illinois).

The problem of determining that combination of design constants which optimizes a certain feature of the response of a system is well suited to solution by analog computers. This is especially true if the feature to be optimized is the time of occurrence or magnitude of an event in the response, such as closure time of a relay or valve or the speed of the moving part at closure. In such cases the quantity to be optimized can only be determined for an individual design by obtaining a solution to the differential equations of motion of the system. For each different set of design constants, the differential equations are the same, but have different parameters. These parameters are determined by the design constants of the system such as weights, lengths, moments of inertia, etc.

The problem of finding the optimum set of design constants is approached in two steps:

1. Systematic Search
2. Gradient Method

In the first step many solutions of the system equations are performed, usually several hundred, each with a different set of design constants. From these many solutions, one or more are chosen which result in the best values for the quantity to be optimized. The corresponding sets of design constants are then used as starting points for Step 2, the Gradient Method. This determines the exact location of the local optimum near each starting point. The best of these local optima is then chosen as the optimum design of the system.

Essentially, Step 1 is a broad general search of all possible areas and Step 2 gives the location of the best design in each of the most promising areas.

It is apparent that a "general search of all possible areas" can involve many trial solutions. A minimum number which would be considered an adequate search would be all combinations of each of two values for the adjustable design constants. For ten design constants, this would mean 2^{10} or 1024 combinations, hence 1024 different solutions to the differential equations. This makes the extremely fast computing speed of the analog of great advantage.

In a recent problem of this type run on the Center's analog computer, the time per solution was about 5 *seconds*. The same problem had previously been programmed on digital equipment of nearly twice the hourly cost. Time per solution on the digital computer was 5 *minutes*. This is typical of the computing speed advantage of analog over digital.

A few solutions were also computed by hand. These took approximately one day each. Comparative costs for 1000 solutions would be as shown in Table 1.

Table 1—Cost of Problem Solution

	Programming	Computing 1000 Solutions	Total
Analog	$2500	$ 62.50	$ 2,562.50
Digital	$3000	$ 6,250.00	$ 9,250.00
Hand	-	$80,000.00	$80,000.00

It is apparent that design optimizations can be performed by the analog method which would be absurd by hand computation, and impractical by digital. The advantage of analog speed can be realized owing to the simplicity with which such large numbers of solutions may be run automatically in this particular type of problem. This is done by use of a binary counter circuit, a number of relays, and hand-set potentiometers. One pot represents each trial value of each design constant. A relay for each design constant chooses one of two values to be used in a given solution. The relays are operated from successive stages of the binary counter. For the case stated before (of trying all combinations of two values for each of ten design constants), 10 relays and 20 pots are required. No more equipment than this would likely ever be needed since additional design constants or additional trial values would be handled by manual resetting after every 1024 runs. The form of a functional relationship can be optimized along with the values of design constants by this method. Here the function is represented by a number of straight-line segments. The value of the function at the end of each segment becomes a new adjustable design constant and is again represented in the computer by either of two pot settings.

The form in which the results appear is of particular advantage. For example, in solving differential equation of motion of a check valve, Channel 1 records the angular position of the valve flapper in responding to a specific flow decrease pattern. Channel 2 records a pulse whose height is the time of closure after flow reversal. This time is the quantity to be minimized in the problem. Channels 3 through 6 record the positions (on or off) of relays which choose different values of the design constants. These relay positions can be considered to be the digits of a binary number by which any particular solution may be identified and related to its corresponding design constants.

1000 such runs would be plotted on a continuous chart about 100 feet long, which is folded and bound in loose-leaf form producing a book of about 150 pages. This is then a reference book by which any particular future variation of the design may be immediately evaluated. The responses appear in binary numerical order and are thus easily located for any chosen set of design constants. Being given in graphical form, they are readily comprehended.

After the talk, Larrowe remarked: "You could extend the range to more than two values of each variable by

using stepping switches instead of relays so that you could have 10 of each."

Sparks: This is just one of the steps of this design optimization procedure. The first search step merely tells you what regions of the space we're talking about are the lower regions. Choose the minimums found in this way to follow the gradient of the function to the true minimum in that area. This technique just locates the lowest general regions in the topography.

Larrowe: What about your bookkeeping on these runs to tell you which run is which?

Sparks: You'll notice on the last sheet of the writeup is an example of the record made for you. The last four channels show the relay positions so they represent a binary number that tells you what response is being measured.

Rideout: This has some resemblance to an adaptive system where you want the system to approach an optimum condition despite the changes in input signal characteristics. You try to go down the path of steepest descent in one way or another.

Sparks: This was what I called step 2 of this optimization procedure to reach the true minima.

Hermann: How did you select the two values of each variable?

Sparks: Pure guesswork on the part of the design engineer.* I think in most cases we assumed one value near the smallest possible value and the second near the largest possible value. By the way, we found two actual solutions that gave good responses and they were entirely different.

Information (Without Theory)

Thomas C. Anderson—author of this month's initial, and we hope, many subesquent "Analog Techniques and Special Circuits"—was born on 6 March 1933 in Chicago, Illinois. He attended the Illinois Institute of Technology in Chicago and received the B.S. degree in Physics in 1955. From 1955 to 1957 he attended the Polytechnic Institute of Brooklyn where he did graduate work in Applied Mathematics. During this period he was also employed as an Associate Engineer at Sperry Gyroscope Company in Carle Place, New York, where he operated an analog computer in the Systems Analysis Organization for a control system study of a guided missile.

Since 1957 Tom has been employed by Lockheed Missiles and Space Division in the Analog Computing Organization, where he has been in charge of the Research Analog Computing Facility.

His article is the first of a series of monthly columns on analog techniques and special circuits which will appear in the *Newsletter*. The column is intended to encourage and speed the exchange of new ideas among the various computing centers around the country. To achieve this, we must receive feedback from readers in the form of criticism, ideas, and techniques that you would like to see presented.

The type of articles desired is somewhat open. As to length, the only requirement is that an article must be long enough to be understandable; a diagram plus a brief explanation would be adequate, or an article just a little too short or narrow in scope of application for a regular paper would be welcome. The subject matter can consist of general techniques, modifications of equipment, etc.

Contributions should be addressed to **J. E. Sherman,** Chairman of the Board, Simulation Councils Inc., Box 504, Sunnyvale, California. He'll see that they are directed to the proper authority for consideration.

We feel that it is a service to our readers to call their attention to the University of Michigan's Engineering Summer Conference on **"Analog Computer Solution of Partial Differential Equations,"** which covers the equations for heat flow and diffusion, structural dynamics, the wave equation, separation of variables and normal coordinates, difference techniques, component error analysis, and passive circuit analogs.

For further info: Engineering Summer Conferences, 126 West Engineering Building, University of Michigan, Ann Arbor, Mich.

He Went Thataway!

Jerry Kennedy to General Manager and Executive Vice President of Applied Dynamics Inc.*, (Ann Arbor, Michigan), "Specialists in Industrial and Process Instrumentation and Controls"—and purveyors of analog computers and components.

*And the better the engineer the better the guess and the less the work. Viva el Ingeniero Profesional Bueno! Ed.—P.E.—B. (??)

*By **Bob Howe** (Charter Member and First Chairman of the Steering Committee of the Midwestern Simulation Council) out of University of Michigan, with assistance of the Gilbert Brothers (and others).

SCI Activities

MATERIAL RECEIVED— TO BE PUBLISHED

Western Simulation Council—Rocky Mountain Simulation Council Joint meeting 10 March 1961 at the University of Arizona.

Thanks to the inspiration and hard work of **Hans Meissinger** (Chairman, WSC), **Maughan Mason** (Chairman, RMSC), **Granino Korn** (Dr. Analog) our host, and many of their colleagues we had one of our best meetings.

And thanks to Hans, **Bill McLean** (Western SC Secretary), and the speakers we have lots to report on this international* meeting.

Program Announcements

Southeastern Simulation Council

14 April 1961, University of Alabama, Tuscaloosa.

"Simulation of a Sampled Data Control System," **Dr. Russell E. Lueg,** University of Alabama.

"Use of a Bristol Pneumatic Process Simulator," **Dr. James D. Matheny,** University of Alabama.

"Use of Plug-in Limiters and Gates," **Mr. James Spear,** Marshall Space Flight Center.

"Applications of the TR-10, Desk Size Analog Computer," by **Al Katz** or **George Martin** of EAI.

Eastern Simulation Council

17 April 1961, **Paul Moore** AR&D Center, Republic Aviation Corporation, Farmingdale, New York on "Simulation in the Aircraft Industry."

"Analog Simulation of Lateral Guidance System for an Unmanned Aircraft," **Richard C. Gilbert,** MSD, Guidance Analysis Section.

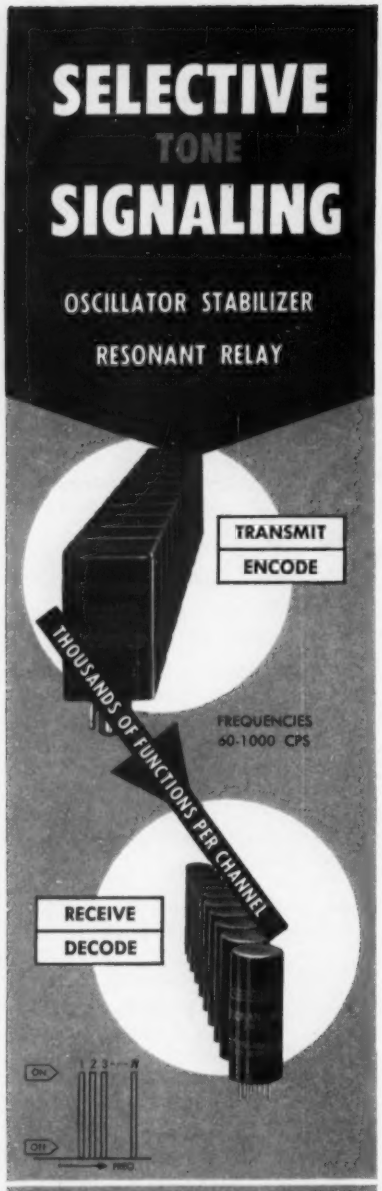
"Application of the Passive Element Analog Computer," **Martin Schmitt,** AR&D, Applied Math Sec.

"Digital Simulation of a Combined Digital-Analog Navigation System," **Norman Nesenoff** and **Ronald D. Goldman,** MSD, Digital Computer Section.

"High Speed Submarine Control Training Simulator," **A. J. Osofsky,** Prod. Eng. Div., Dynamics Analysis Section.

"Techniques for Study of Feedback Control Systems Subject to Stochastic Inputs," **George Brandeau,** MSD, Control Analysis Sec.

*Through the participation of **Rajko Tomovic** of the Institute Boris Kidric in Belgrade.



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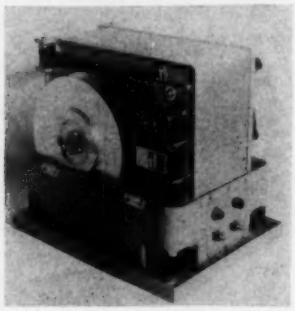
CIRCLE 98 ON READER-SERVICE CARD

ICS NEW INSTRUMENTS

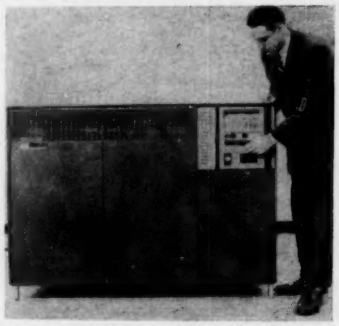
PORTABLE DIGITAL RECORDING SYSTEM



New transistorized Type 6150 Incremental Digital Recording System acquires asynchronous data by a tape stepping method. At nominal stepping speed of 30 steps/sec (200 steps/in of tape), 38 hours of continuous recording are handled with one reel of tape. At lower sampling speeds, the tape supply from one reel often is adequate to permit unattended, automatic operation for a year or longer. Power requirement is only 8 w, which enables it to be operated with two standard 12-v automobile batteries, if standard power sources are not available. Normal power needs are 60 to 400 cps, 1/95-125 v ac. Track widths and spacings are compatible with most standard computers or data transcribing units.—*Minneapolis-Honeywell, Industrial Systems Div.*, 10721 *Hanna St., Beltsville, Md.*

CIRCLE 236 ON READER-SERVICE CARD

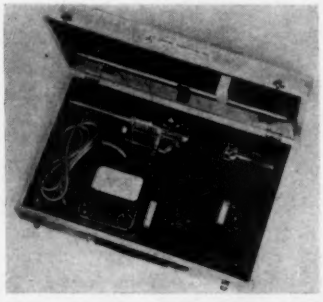
COMPUTER CONTROL SYSTEM



New IBM 1710 Control System for process optimization, process study, and manufacturing quality control consists of the new 1711 data converter connected to the solid-state IBM 1620 computer. In process study, it performs various mathematical analyses such as correlation and regression studies. In process optimization, it furnishes guides to the operator as a result of calculations performed on sampled data. In quality control, the system takes frequent instrument readings of products undergoing final test. The basic 1620 has 20,000 positions of magnetic core storage which can be expanded to 40,000 or 60,000 positions. A variable word length system, the 1620 is able to make 100,000 calculations a minute.—*International Business Machines Corp., Data Processing Div.*, 112 *E. Post Rd., White Plains, N. Y.*

CIRCLE 238 ON READER-SERVICE CARD

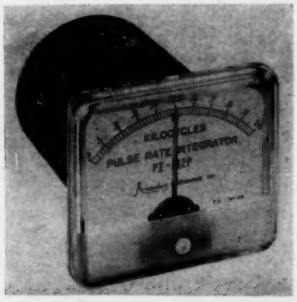
PORTABLE PSYCHROMETER



New A+ Hygrophil improved portable Thermistor Psychrometer uses tiny thermistor beads as resistance thermometer elements, built-in fan system. Temp indicated on 3 overlapping scales in increments of ½°F or 0.2°C; relative humidity accurate to 0.5% over most of scale. Bulletin.—*Atkins Technical, Inc.*, 1276 *W. 3 St., Cleveland* 13, *Ohio.*

CIRCLE 237 ON READER-SERVICE CARD

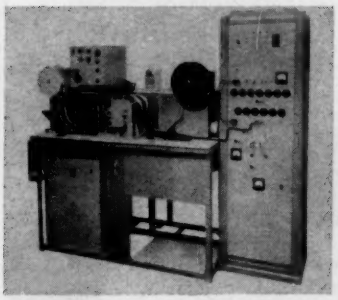
PULSE RATE INTEGRATOR



New Series PI-111 Pulse Rate Integrator monitors power line frequencies, turbine flow sensors, and other frequency generating devices from 57-63 cps, 380-420 cps, and 50 cps-50 kc. Features input sensitivity as low as 10 mv rms, 0.1% resolution.—*Anadex Instruments, Inc.*, 14734 *Armint St., Van Nuys, Calif.*

CIRCLE 239 ON READER-SERVICE CARD

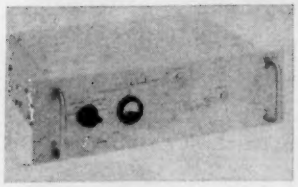
SORTER, BRIDGE



New TCS-AB4 Taped Component Sorter and new Model AB-5-1, 1-MC Limit Bridge features automatic feeding and sorting.—*Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. J.*

CIRCLE 240 ON READER-SERVICE CARD

QUARTZ OSCILLATOR



New transistorized Quartz Oscillator, Model 103AR, features long-term stability of 5 parts in 10^{10}/day. Provides two sinusoidal output signals, 1 mc and 100 kc, from a low source impedance at a power level suited for distribution over 50-ohm systems.—*Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif.*

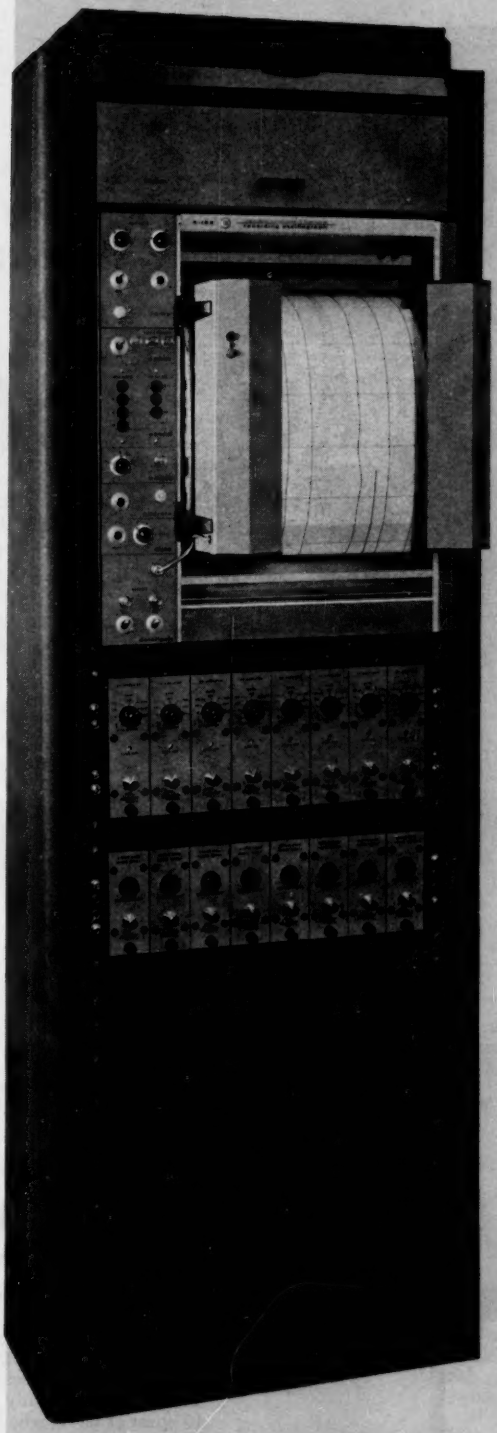
CIRCLE 241 ON READER-SERVICE CARD

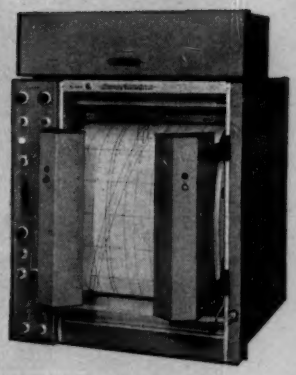
TERMINAL BOARDS

Military Terminal Boards; toggle switches with female-clip terminals, as well as standard screw-type and solder type; Kliptite hardware; 600 Series barrier terminal blocks; special devices to meet unusual requirements were displayed at IRE exhibit.—*Kulka Electric Corp., 633-643 S. Fulton Ave., Mt. Vernon, N. Y.*

CIRCLE 242 ON READER-SERVICE CARD

CIRCLE 199 ON READER-SERVICE CARD→





IMMEDIATE DATA ...MOUNTING VERSATILITY

...get both with this recording oscillograph

Rack it vertically...stand it on a bench...use it on a table! CEC's 5-123 Recording Oscillograph delivers print-out data immediately with exclusive "DATAFLASH"* that produces traces 60 times faster than any other print-out process. This modular design instrument gives you immediate access to clear, readable data while recording at 16 ips.

Along with unmatched mounting versatility, the 5-123 offers the advantages of non-chemical processing using standard print-out papers—and with no latensification delay. Its other key advantages include full front accessibility and pushbutton controls to change speeds instantly from 0.1 to 160 ips while recording 36 to 52 channels of data.

***Patent Pending**

For complete information, contact your nearest CEC sales and service office, or write for Bulletin CEC 1623-X18.

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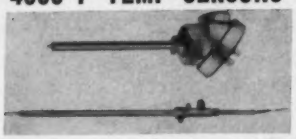
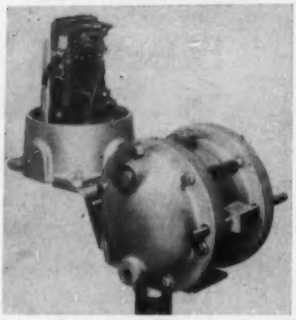
4000°F TEMP SENSORS



New thermocouple-type non-cooled and cooled Temperature Sensors measure liquid, solid, and gaseous temps in oxidizing atmosphere up to 4000°F and intermittently higher. Thermocouple wires are iridium, tungsten, rhenium and alloys of these elements. PIR Report 8.1—*Aero Research Instr. Co., Inc., 315 N. Aberdeen St., Chicago 7, Ill.*

CIRCLE 243 ON READER-SERVICE CARD

FLOW TRANSMITTER



New Chronoflo Bellows Actuated Flow Transmitter is for pressure-operated, explosion-proof remote flow metering service in pipe line distribution of gas or other hazardous materials. Working pressure is up to 1000 psig with standard construction. Transmitter and receiver operate over any telemetering line. Time cycle of 8 sec is standard; accuracy is ±1% of span over a range of from 10% to 100% of span.—*B-I-F Industries, 345 Harris Ave., Providence, R. I.*

CIRCLE 244 ON READER-SERVICE CARD

DIAL-O-VERTER SYSTEM

New D755 High-Speed Tape Distributor drives up to six output punches and distributes incoming data to any one or more of the six output paper tapes, when connected to a D3590 paper tape reader.

New D560 Switching Unit provides a means whereby either one of two D599SR couplers may be connected to any one of three individual digital Data-Phone subsets. Receiving signals from one Data-Phone subset, it feeds regenerated signals to a second Data-Phone subset as well as to the local Dial-o-Verter terminal.—*Digitronics Corp., Albertson Ave., Albertson, L.I., N. Y.*

CIRCLE 245 ON READER-SERVICE CARD

How round wire helps make

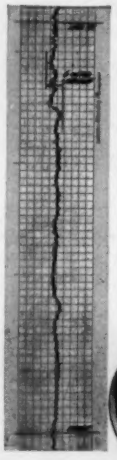
GOOD POTENTIOMETERS BETTER!

The rounder the wire the easier it is to obtain greater uniformity of spacing in winding potentiometer mandrels...

and the more uniformly wound the mandrel the easier it is to achieve

closer independent linearity and lower equivalent noise resistance in your finished potentiometers.

This enlarged photograph shows typical uniformity of winding that is readily obtainable with



HOSKINS

Chromel-R

Premium Potentiometer Grade Wire

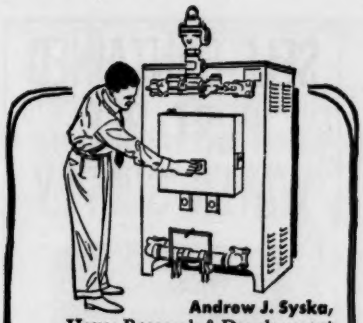
• A new nickel-chromium alloy that is quality-controlled from melt to spool to assure superior roundness and surface finish—closer linearity of resistance, within .012% maximum total deviation in every 250 feet of wire—plus lower electrical noise level, unconditionally guaranteed to be less than 40 ohms of ENR when received at your plant.

Sample spools with supporting technical data are now available to potentiometer manufacturers for immediate testing and evaluation. Your request on company letterhead will receive prompt attention.

HOSKINS MANUFACTURING COMPANY

4445 Lawton Avenue · Detroit 8, Michigan

In Canada: Hoskins Alloys of Canada, Ltd., Toronto, Ontario



Andrew J. Syska,
Hayes Research & Development Engineer Reports . . .

KNOW-HOW IS VITAL IN GAS AND LIQUID DRYING

When we developed the Molecu-Dryer®—a unit specially designed to take advantage of the remarkable drying, sweetening, and purifying capabilities of Linde Company's Molecular Sieves—our chief interest was in drying protective atmospheres (hydrogen, dissociated ammonia, etc.) for metallurgical work—to dewpoints well below –100°F. A natural outgrowth of the Molecu-Dryer was the *Nitro-Gen** —an automatic cycling generator which produces low cost, high purity nitrogen for blanketing, purging, protecting. Our engineering people have also explored whole new worlds of gas, liquid, and atmosphere drying and separating problems.

NEW DRYING NEEDS APPEAR DAILY

In manufacturing transistors, for example, the Molecu-Dryer has been able to effect big economies by supplying moisture-free air in place of tank nitrogen to protect transistor assembling and sealing operations. Other current projects: instrument air drying, gaseous CO_2 drying, gas separating . . . also drying and separating of liquid or gaseous hydrocarbons.

EQUIPMENT DESIGN IS DYNAMIC!

Each new area of work has necessitated engineered application of standard or special Molecu-Dryer models, to provide optimum adsorption efficiency, top capacity at minimum equipment cost, job-coordinated cycle times, and fast desorption and cooling.

Linde MOLECULAR SIEVES ®

For a comprehensive picture of the Molecu-Dryer, write for Bulletin 5703.

*Hayes TM

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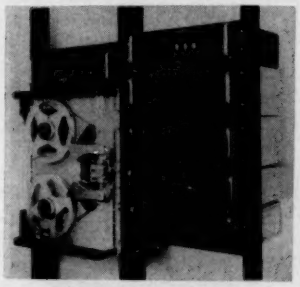
Established 1905

It pays to see Hayes for metallurgical guidance, lab. facilities, furnaces, atmosphere generators, gas and liquid dryers, Pow-R-Trol (TM) control units.

CIRCLE 100 ON READER-SERVICE CARD

SPECTRUM ANALYZER



New Vibracoder system performs spectral density analysis of dynamic data. Random or periodic signals representing strain, vibrations, pressure fluctuations, voice and communications signals are presented on-line for analysis. Energy distribution is over a bandwidth of 5000 cps with a resolution of 50 cps. Distributed energy is encoded at a rate of 5000 readings/sec and placed on ½" magnetic tape in compatible form for direct entry to IBM equipment. Accuracy is better than 1%.—*Communications Control Corp., 14707 Keswick St., Van Nuys, Calif.*

CIRCLE 246 ON READER-SERVICE CARD

DC VOLTMETER

New transistorized d-c Voltmeter, Model V-70, covers d-c range from 1 mv to 999.9 v. Features include rapid response time and absolute accuracy of 0.01%, ±one digit. Balance time is 500 msec and maximum readout time is 750 msec.—*Cubic Corp., 5575 Kearny Villa Rd., San Diego 11, Calif.*

CIRCLE 247 ON READER-SERVICE CARD

AC/DC DIGITAL SYSTEM

New AC Power Converter, Model AC-45, for twin mounting with its companion V-45 DC Digital Voltmeter, provides a precision ac/dc digital system. The transistorized converter has a floating input which can be utilized up to 500 vdc above ground. Combined with voltmeter it permits measurement of voltages from 1 mv to 1099.9 vac to accuracy of ±0.25% of full scale over a frequency range of 60 cps to 5 kc.—*Cubic Corp., 5575 Kearny Villa Rd., San Diego 11, Calif.*

CIRCLE 248 ON READER-SERVICE CARD

Lepel

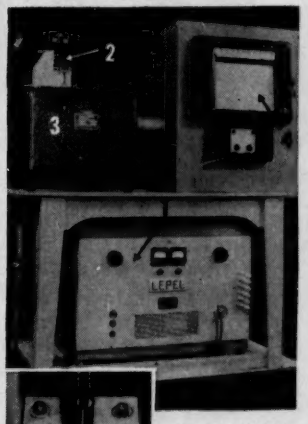
HIGH FREQUENCY *Induction* HEATING UNITS

Lepel induction heating equipment is the most practical and efficient source of heat developed for numerous industrial applications

Simultaneous Mechanical and Thermal Cycling

Simulated Performance Tests Aided by Induction Heating

Equipment designed to evaluate performance of aircraft and missile components subject to repeated mechanical stress at elevated temperatures.



Use of a 2½ KW Lepel generator (1), and induction coil (2), permits induction heating of metallic and cermet materials to constant and varying temperatures while under repeated mechanical stress applied by cantilever-type fatigue testing unit (3). Very rapid heating (several hundred degrees per second) and cooling, permit thermal pulses to simulate sudden temperature changes in actual service.

Close temperature control (±3°F) for long periods of time, to temperatures exceeding 2400°F is accomplished with control system (4). This permits fatigue testing over a wide range of temperatures.

Our engineers will process your work samples and return the completed job with full data and recommendations without cost or obligation.

WRITE FOR NEW LEPEL CATALOG

Lepel HIGH FREQUENCY LABORATORIES, INC.

55th ST. & 37th AVE., WOODSIDE 77, N. Y.
CHICAGO OFFICE: 6246 WEST NORTH AVE.

CIRCLE 101 ON READER-SERVICE CARD

STOP

- **Lost Batches in Process**
- **Data Reruns**

because of battery rundowns

New recorder voltage supply

replaces laboratory and industrial potentiometer standard and dry cells.

- *Stop excessive man hours for standardizing checks, battery replacements and mechanical repairs.*
- Used in most potentiometers made by: Leeds & Northrup, Foxboro, Bristol, Minneapolis-Honeywell, and others.
- *Interchangeable between instruments because of external shunt resistor.*
- BATT-SUB is available in two models:
  BS-1 replaces dry cell only
  BS (TC)-1 replaces dry and standard cells.

Low Priced:

Model BS-1 .....$59.00
Model BS(TC)-1 .....$64.50
(Delivery stock to 3 weeks)
Write for specifications bulletin PS100-1 or order your BATT-SUB directly from Dynage.

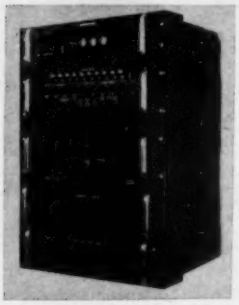
DYNAGE, INC.

390 CAPITOL AVENUE HARTFORD CONNECTICUT

Telephone CHapel 9-5654

CIRCLE 102 ON READER-SERVICE CARD

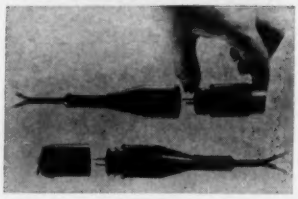
MULTI-CHANNEL DATA SYSTEM



New CANDU-FAX system allows transmission of signals as small as 10 mv for distances up to 1000 miles with accuracies of 0.1%. Monitors up to 250 channels of low-level or high-level data, representing temperatures, pressures, displacements, and voltages. Steps from one channel to the next at ten readings/sec, converting data into numerical form transmitting them via radio, leased line, or even telephone handset. Received data, channel, and other pertinent information are printed, taped and/or perforated. Original analog signals are restored at high level.—*Communications Control Corp., 14707 Keswick St., Van Nuys, Calif.*

CIRCLE 249 ON READER-SERVICE CARD

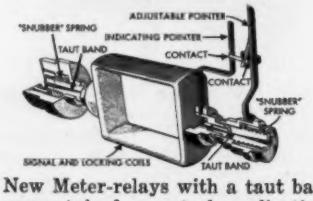
THERMOCOUPLE HEAD



New Quick Disconnect, 2400 Series, has base and terminals deeply imbedded in a tough, waterproof and weatherproof molded neoprene body. Connector pins are sized (polarized and staggered in length) to eliminate possibility of reverse polarity.—*Gay Sales Co., 13232, Houston 19, Tex.*

CIRCLE 250 ON READER-SERVICE CARD

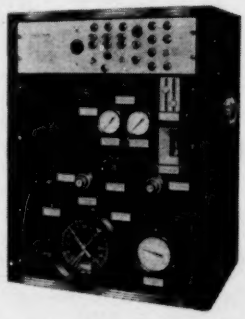
METER-RELAY



New Meter-relays with a taut band movement is for control applications requiring high full-scale sensitives. Features include coil springs, incorporated in "snubber" mechanisms at both ends of the meter movements. Offered in sensitivities of 0 to 5, 10, 20 and 50 μamp, and 0 to 2, 5 and 10 mv.—*Assembly Products, Inc., Chesterland, Ohio.*

CIRCLE 251 ON READER-SERVICE CARD

SELF-CONTAINED PORTABLE WATER SUPPLY



MAINTAINS TEMPERATURE OF ELECTRONIC EQUIPMENT TO ± 1° F

MODEL E-1147-1
POWERTHERM®

BOTH WATER TEMPERATURE AND FLOW RATE DELIVERED TO EQUIPMENT ADJUSTABLE OVER WIDE RANGE

- Temperature Controlled to ±1°F From 40°F to 150°F
- Flow From 0 to 2.7 GPM at 55 PSI

COMPLETELY SELF-CONTAINED AND TOTALLY ENCLOSED SYSTEM

- 2 Gallon Stainless Steel Tank
- Complete Refrigeration System Cools up to 1.5 KW
- Heater Supplies up to 1 KW
- Self Sealing Connectors

FOOLPROOF FAIL-SAFE AUDIO-VISUAL ALARM SYSTEM

- Adjustable High-Low Flow Rate and Temperature
- Low Water Level
- High Pressure

ELECTRONIC EQUIPMENT INTERLOCK PROVISIONS

- Automatic Equipment Shut Off in Conjunction with Alarm

COMPACT HOUSING

- Overall Dimensions: 28"x22"x15"
- Bench Model with Handles

Other Models also Available
Contact us for more detailed information or to discuss your specific requirements

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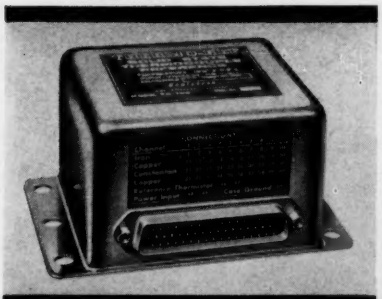
TWX: BURL MASS 761u

CIRCLE 103 ON READER-SERVICE CARD

A major breakthrough in temperature measurements!



THE NEW thermo-ref solid-state thermocouple reference

The new Genistron Thermo-Ref provides a constant reference temperature of 100°C., ±0.1°C., with a 10-channel uniformity of ±0.1°C. Maximum drift is less than 0.5°C. over an ambient temperature range of −55°C. to +85°C. Power consumption is a nominal of 1.0 watts over a voltage variation of 95 to 125 volts AC. These specifications and its small size and light weight make the Thermo-Ref ideal for airborne applications. Standard models are available for reference temperatures of 100°C., 121°C. and 150°C.

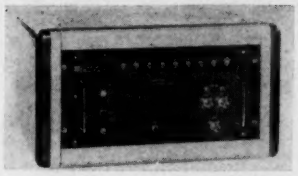
The Thermo-Ref measures 3⅛"x3¼"x2" and weighs approximately 12 ounces. Packaging and environmental conditions meet or exceed MIL-E-5272 and MIL-E-16400.

Write for complete technical information.

Genistron
A subsidiary of Genisco Inc.
6320 WEST ARIZONA CIRCLE
LOS ANGELES 45, CALIFORNIA

CIRCLE 104 ON READER-SERVICE CARD

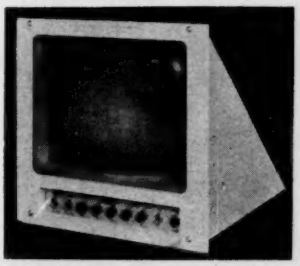
100 MC COUNTER-TIMER



New Model 1060 solid-state Counter-Time interval meter features 10-nano-second resolution and max counting rate of 100 Mc. Also available is a digital interpolator which improves resolution to better than 0.1 nanosecond. Storage is 10^9 counts.—*Eldorado Electronics*, 2821 *Tenth St., Berkeley* 10, *Calif.*

CIRCLE 252 ON READER-SERVICE CARD

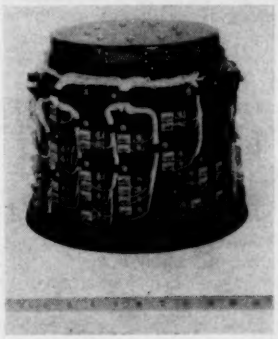
DATA DISPLAY SCOPE



New Model MS-2 Data Display Oscilloscope features solid-state circuitry and self-contained power supply. Occupies only 17½" of relay rack space and consumes 230 watts of power. Typical application is bar graph display of time multiplexed telemetering channels.—*Kauke and Company, Inc.*, 1632 *Euclid St., Santa Monica, Calif.*

CIRCLE 253 ON READER-SERVICE CARD

MAGNETIC STORAGE DRUM



New Magnetic Storage Drum employs contact read/write heads to achieve large capacity, nonambiguous storage of digital data. Surface air movement causes the heads to rise a few millionths of an inch from the surface when drum reaches its operating turning speed. Write currents are 3.5 to 5 amp turns, compared with 15 amp turns for fixed heads. Read signals are also high, with a one-volt signal obtainable. Minimum write current is 300 mv.—*Litton Systems, Inc., Computer Systems Lab.*, 5500 *Canoga Ave., Woodland Hills, Calif.*

CIRCLE 254 ON READER-SERVICE CARD

STOP

Standard Current Drifting in laboratory potentiometers

New DYNAGE BATT-SUB BS (TC)-2

is a reliable, constant DC voltage supply for lab potentiometer.

- *Replaces drift prone wet storage batteries and dry cells.*
- Typical applications:
  Leeds & Northrup
  Model K2 (3 v, 20.0 ma)
  Model K3 (3 v, 24.44 ma)
  Rubicon
  Models 2760, 2780, 2781, (3 v, 11.0 ma)
- Voltage stability: ±.001%/% input change
- Temp. stability: ±0.001%/°C over range of 15°C to 35°C

Low Priced . . . $95.00

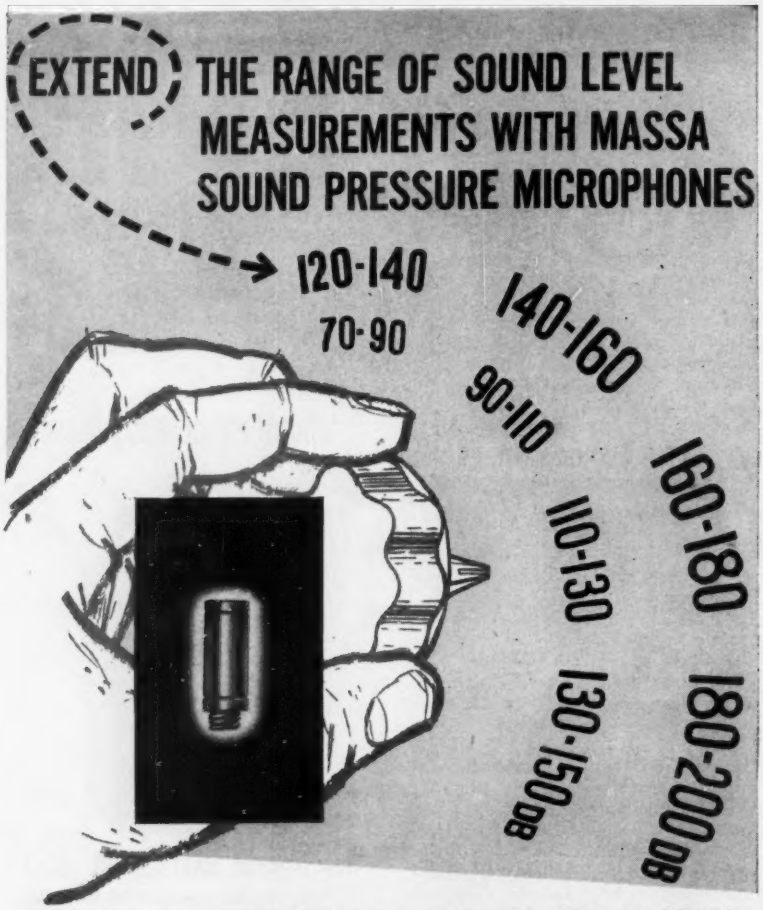
Delivery: Stock to 3 weeks
(Specify voltage and current requirements when ordering)

- Order your **BATT-SUB** today directly from **Dynage**, or write for complete specifications.

DYNAGE, INC.

390 CAPITOL AVENUE
HARTFORD CONNECTICUT
Telephone CHapel 9-5654

CIRCLE 105 ON READER-SERVICE CARD



AVAILABLE IN FREQUENCIES FROM 20 CPS to 90 KC

Massa Sound Pressure Microphones employ ADP (Ammonium DiHydrogen Phosphate) crystals as the active elements for the best combinations of *reliability, stability,* and *accuracy.* These proven microphones are in widespread daily use in highly critical fundamental acoustic measurements over both the audible and ultrasonic ranges.

For example, in the study of scaled-down test jet and rocket engines, the resonant frequencies reach well into the ultrasonic frequency range. Without adequate microphones subtle sonic waveforms, indicative of expected full scale sounds, will be missed.

Massa Sound Pressure Microphones Provide:

- **EXCLUSIVE ADP Crystals:** For maximum reliability, stability, and accuracy.
- **Wide Frequency Range:** From as low as 20 to as high as 90,000 cps.
- **Wide Dynamic Range:** Linear to Sound Pressures in Excess of 200 db.*
- **Near Infinite Acoustical Impedance:** No loading of sound field.
- **Omni-Directional Pattern:** For sure pickup of sound in difficult areas.
- **Small Size:** Diameters from 5/8 inch to less than 1/4 inch . . . for easy probing of small cavities.

*above 0.0002 microbars.

There is a complete line of Massa Sound Pressure Microphones from which you may select the unit best suited to your application.

Massa designed and manufactured companion equipment, Adaptors, Pre-Amplifiers, and Power Amplifiers are available to facilitate installation.

Write for Technical Bulletin SPM-5

MASSA
A DIVISION OF
COHU
ELECTRONICS, INC.
276 LINCOLN STREET
HINGHAM, MASSACHUSETTS

OTHER MASSA PRODUCTS

COMPLETE LINE OF
MULTICHANNEL AND PORTABLE RECORDING SYSTEMS

ACCELEROMETERS
HYDROPHONES
MICROPHONES
AMPLIFIERS
SONAR TRANSDUCERS

CIRCLE 106 ON READER-SERVICE CARD

DC AMPLIFIER

New solid-state, direct-coupled differential-input airborne DC Amplifier for rugged operational environments is 4.75 cu in, weighs 6 oz. Equivalent input drift is less than ±100 mv for 8 hr; gain variation is ±1% to 5 kc, 3 db down at 30 kc, input 5 mv, output ±5 v into 20 k. Absence of chopper eliminates hash, permits extended frequency response, allows rapid recovery from overloads.—*Microdot Inc., 220 Pasadena Ave., South Pasadena, Calif.*

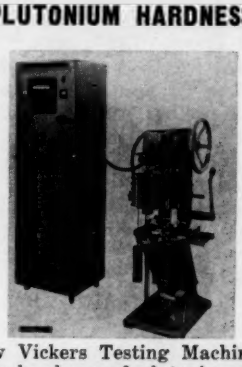
CIRCLE 255 ON READER-SERVICE CARD

ANALOG DATA RECORDER

New Model 102A portable 2-channel Record/Reproduce System has 0.2% precision in recording and reproduction of all analog data from 0-400 cycles; uses pulsed FM principle and transistorized circuitry. Features: 3 tape speeds, wide dynamic range, independent record and reproduce channels.—*Mnemotron Corp., 3 N. Main St., Spring Valley, N. Y.*

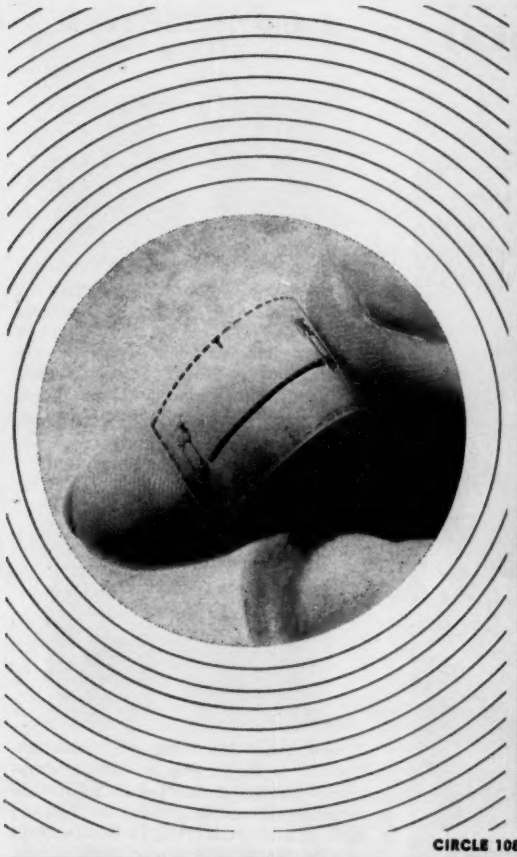
CIRCLE 256 ON READER-SERVICE CARD

PLUTONIUM HARDNESS



New Vickers Testing Machine for testing hardness of plutonium is for glove-box operation and equipped with operating controls, 1800°F electric furnace, indexing compound and microscope.—*Riehle Testing Machines, Div. American Machine and Metals, Inc., East Moline, Ill.*

CIRCLE 257 ON READER-SERVICE CARD



Orders of Magnitude More Sensitive

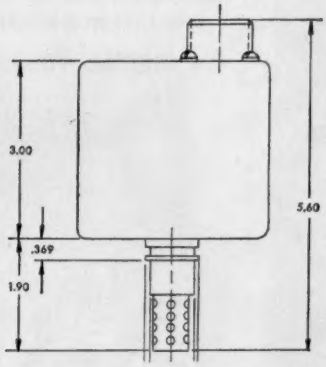
MICRO-SENSOR MS 105-350

FEATURING

CIRCLE 108 ON READER-SERVICE CARD

Liquid Level Warning System

The most significant feature of this system is that the electronic control package can withstand very high temperatures.



During operation, the indicating circuit remains "off" until the oil level drops to a predetermined point and a warning light flashes; and in testing, the entire circuit can be instantly checked by means of a "press to test" button. A major advantage of the sensing concept used is that the unit does not give a false reading when the probe is temporarily uncovered by oil from such causes as an aircraft's assuming unusual attitudes or undergoing negative G's . . . (*From Data Sheet 1B-4.1-AB, Hamilton Standard Electronics, United Aircraft Corp., Section D-60, Broad Brook, Conn.*)

CIRCLE 386 ON READER-SERVICE CARD

Here's the NEW Dillon force control switch

Different Ranges: From 0-100 lbs. up to 0-50,000 lbs.

Triggers motors, rings bells, operates warning devices, etc.

Protected against accidental overloading.

Tensile or Compression Models available.

- Furnished with from 1 to 4 adjustable switches for controlling forces at various load points.
- Can be set for most critical accuracy.

WHAT CAN IT DO FOR YOU?

Write for specifications, profusely illustrated literature and low price schedule . . . free!

W. C. Dillon & COMPANY, INC.

Dept. 113, 14584-8 Keswick Street, Van Nuys 75, Calif.

CIRCLE 387 ON READER-SERVICE CARD

OPTIMUM RETURNS THROUGH QUALITY CONTROL

• **A proved cost-cutter,** now operating in over fifty refineries, gasoline, and chemical plants. • **Increases yield and improves quality** by accurately and **continuously** monitoring ASTM end-point. Delays between quality change and compensating control are eliminated. Allows closer operation to end-point specifications. • **Reproducibility** far exceeds laboratory method. • Write for Technical Bulletin 5900-11.

Totco also makes an Initial Boiling Point Analyzer. Write for Technical Bulletin 1259-11.

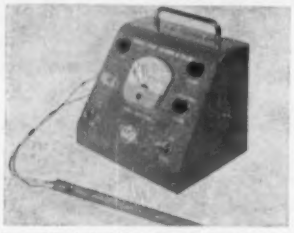
MANUFACTURERS OF PRECISION INSTRUMENTS SINCE 1929

TOTCO

TECHNICAL OIL TOOL CORPORATION
1057 North La Brea Avenue, Los Angeles 38, California • OLdfield 4-1763
Gulf Coast Representatives: The Mott Co., 1719 McKinney, Houston 1, Texas

CIRCLE 109 ON READER-SERVICE CARD

LIQUID NITROGEN CONTROL



New Model SEL 130 Liquid Nitrogen Control Unit is for use with high vacuum processing equipment. Has thermistor sensing element.—*Scientific Engineering Laboratories,* 1510 *Sixth St., Berkeley* 10, *Calif.*

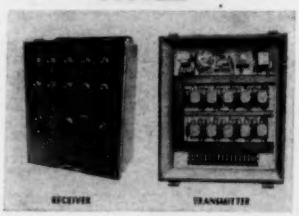
CIRCLE 258 ON READER-SERVICE CARD

THERMOSTAT

New Dualstat serves where an overrun of even one cycle cannot be tolerated. Sentinel is set a few degrees above the control and shunts the load through a heater next to the control to open the contacts. Has snap action with 3°F (or better) differential. Capacity is 2 amp, 28 v and 150 w, 120 v dc-ac.—*Valverde Laboratories,* 252 *Lafayette St., N. Y.* 12, *N. Y.*

CIRCLE 259 ON READER-SERVICE CARD

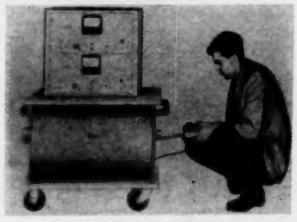
ALARM TELEMETERING SYSTEM



New Model AT-100, consisting of transmitter and receiver, features continuous monitoring of up to 50 alarm signals, a 2-wire transmission system, up to 20-mile transmission, and audible and visual alarm. Operates on 115-v, 60-cps ac.—*Instruments, Inc., Box* 556, *Tulsa, Okla.*

CIRCLE 260 ON READER-SERVICE CARD

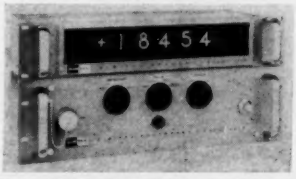
RADIOACTIVITY



New Fluid Monitoring System consists of a Model FMS-1 mobile sampling tank, and Model LCRM-22 logarithmic count ratemeter for detecting and measuring radiactivity in gas or water. Monitors stack gases, cooling loops, etc. Two detectors available: A GM detector for gross beta-gamma, and a NaI scintillation detector for a specific gamma energy, or gross gamma.—*Nuclear Measurements Corp.,* 2460 *N. Arlington Ave., Indianapolis, Ind.*

CIRCLE 261 ON READER-SERVICE CARD

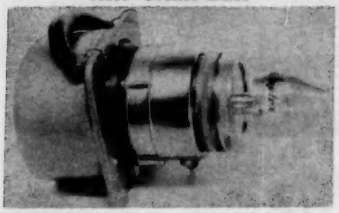
DIGITAL VOLTMETER



New 501B DC Digital Voltmeter measures positive or negative unknowns between 100 μv and 1000 v. Model 456B Digital Voltmeter Control unit contains the metering circuits, while the measured values are displayed on a 473A Digital Readout. Provides useful accuracy of a five-digit voltmeter while retaining the stability, reliability, and price advantages of four-digit instrumentation. Features include 100% overranging above standard 4-digit instruments, single-plane wide-angle readout, accuracy of 0.01% ±1 Digit.—*Kintel Div. of Cohu Electronics, Inc.,* 5725 *Kearny Villa Rd., Box* 623, *San Diego* 12, *Calif.*

CIRCLE 262 ON READER-SERVICE CARD

AIR SAMPLER



New Annular Kinetic Impactor Head for use with air sampler FMC by the Air Sampler is capable of sampling air at a rate of approximately 50 cfm equivalent to 454 LF/S per second. Collection efficiency is 95% for particles above 0.4 μ in diameter which have a density greater than 15 gm/cm^3. Utilizes a turbine type blower.—*Air Sampler Div., Staplex Co., 777 Fifth Ave., Brooklyn, N. Y.*

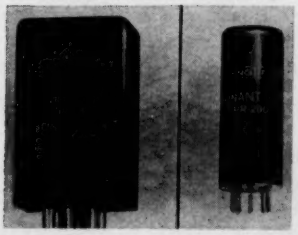
CIRCLE 263 ON READER-SERVICE CARD

PICKUP COIL

New electromagnetic Pickup Coil with integral transistorized amplifier, Model MA-3G, is for use with Waugh turbine flow sensors or can be used separately as a magnetic motion pickup in tachometer applications. Voltage gain is 15:1 with a power gain of 100:1. Ideal for impedance matching and for applications where long transmission distances exist between the point of measurement and the readout equipment. Bulletin 115.—*Waugh Engineering Co., 7842 Burnet Ave., Van Nuys, Calif.*

CIRCLE 264 ON READER-SERVICE CARD

TUNING-FORK RELAYS



New Stevens-Arnold Tuning-Fork Resonant Relays are miniature, plug-in components installed at the receiving end of low cost selective calling or remote control systems and operate only when energized at their rated frequency. Tuning-Fork Oscillator Stabilizer, a companion item, is installed at the transmitting end to stabilize the vacuum tube or transistorized oscillators which supply accurate control tones to energize and operate corresponding Resonant Relays at the receiving end. Both items for frequencies from 150 to 1000 cps. Catalog 564.—*Stevens-Arnold, Inc., 7 Elkins St., South Boston 27, Mass.*

CIRCLE 265 ON READER-SERVICE CARD

NOW, AVAILABLE FAST
FROM 12 NATIONWIDE STOCKING POINTS

TRINITY THERMOWELLS
The Industry's Most Complete Line

Only TRINITY, the industry's leading manufacturers of thermowells, has the facilities and sales volume to institute such a dynamic service designed to fill your emergency needs from a nationwide network of twelve stocking points.

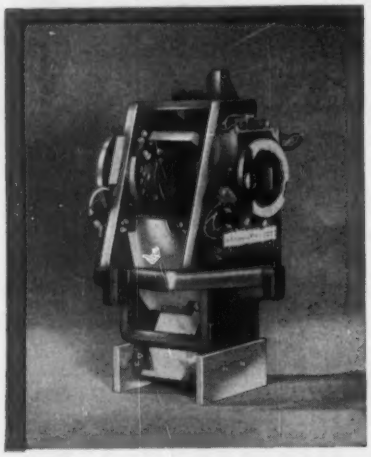
NOW, your TRINITY representative can deliver standard thermowells at factory prices from Baton Rouge, Chicago, Cleveland, Houston, Los Angeles, New York City, Omaha, S. Charleston, Tulsa, and Toronto and Calgary in Canada.

NOW, you can rely on TRINITY's central inventory at Cortland, New York. Already, it includes many hundreds of ready-to-ship well types stocked in depth, and it is still growing. So even for unusual requirements, you can be sure of same-day shipment you often need.

TRINITY

CIRCLE 110 ON READER-SERVICE CARD

PRECISE STAR TRACKER



A celestial navigation system called for a tracking device capable of establishing a line of position within an accuracy of 300 feet. Kollmorgen came up with a constant deviation elevation system that positions a movable mirror, in relation to the fixed elements, to a repeatable accuracy of better than 5 parts in a million.

This compact package represents a combination of highly precise optical and electronic units in a housing only 6 x 6 x 10 inches. Kollmorgen's project from concept to installation, it is a typical demonstration of the company's scientific, engineering and manufacturing skills in optics, electronics, mechanics. Example: the precision optics (a prism and two mirrors) are of Kollmorgen manufacture. So, too, are the Inland torque motor*, the gearing and other precision-machined parts.

Our motive in this message: Kollmorgen offers proven capabilities in optics, electronics and precision machining of metal components . . . capabilities which could solve your problems in missile tracking, fire controls, navigation, or . . .?

Present us with a problem.

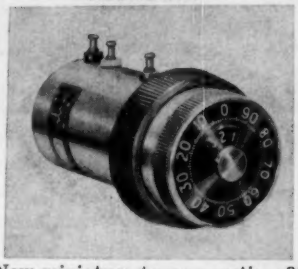
*Product of Inland Motor Corporation of Virginia, a Kollmorgen subsidiary.

Dept. 12-5

KOLLMORGEN CORPORATION
NORTHAMPTON, MASSACHUSETTS

CIRCLE 111 ON READER-SERVICE CARD

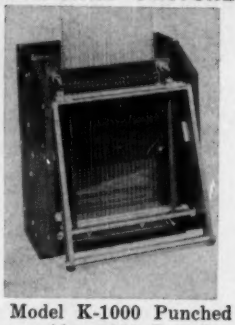
MICRODIAL



New miniature turns-counting 3000 Series Microdial, 1" in dia, or 1-5/32" with addition of a finger-tip brake, projects from a panel only 15/16" and can be grouped as closely as 1¼" centers. Used for accurate angular positioning of any precision potentiometer or shaft-controlled device of ten turns or less.—*Borg Equipment Div., Amphenol-Borg Electronics Corp., 120 S. Main St., Janesville, Wis.*

CIRCLE 266 ON READER-SERVICE CARD

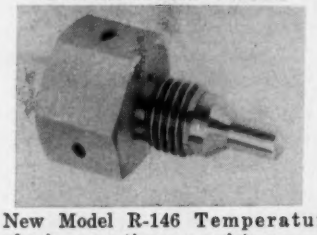
PUNCH-CARD SWITCHES



New Model K-1000 Punched Card Switch provides 1000 Switches operable from a card of twenty rows by fifty columns. Separate switch for each hole position. Punched holes have closed switches, unpunched holes have open switches.—*Taurus Corp., Academy Hill, Lambertville, N. J.*

CIRCLE 267 ON READER-SERVICE CARD

TEMPERATURE PROBE



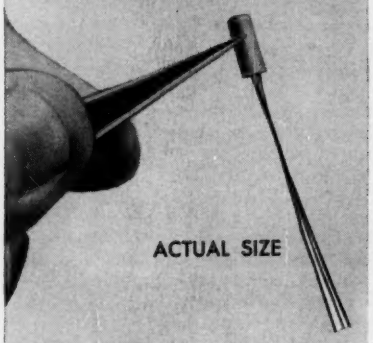
New Model R-146 Temperature Probe is a continuous-resistance output transducer, completely encased in a rugged, one-piece 303 s.s. housing for difficult environmental conditions such as in liquid, vapor or gas applications. Utilizes stabilized alloy wire as a sensing element. Range is —100° to 400°F. with calibration accuracy of better than ±5°F (±1.5°F, special.) Time operating pressure is 5,000 psig with burst pressure in excess of 10,000 psig.—*Quantatron, Inc., Instrumentation Div., 4201 Redwood Ave., Los Angeles 66, Calif.*

CIRCLE 268 ON READER-SERVICE CARD

NEED TO SENSE TEMPERATURE TO 0.05°F. *ACCURATELY AND REPEATABLY*

THEN YOU SHOULD HAVE MINCO'S MODEL S-31

PRECISION RESISTANCE THERMOMETER



- Repeatability accuracy better than 100 parts per million.
- Strain-free platinum sensing element.
- Hermetically sealed — vibration and shock protected.
- High impedance level — 470 ohms at ice point.
- Large output — approximately 1 ohm per 1°F change.
- Range: —100°F to +400°F.
- Initial shipment made within 24 hours when requested.
- Prices range from $54 to $124, depending on quantity and calibration accuracy specified.

FREE PRODUCT FOLDER OF THERMAL-DEVICES

Request EEM-5300 file for technical data about Heaters, Thermal-Ribbons, Thermal-Indicator, Resistance Temperature Detectors, and Precision Resistance Thermometers.

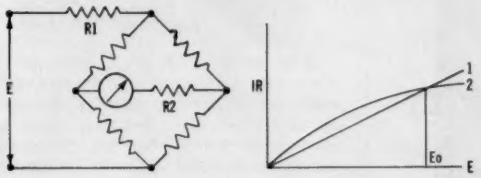
MINCO PRODUCTS, INC.

740 Washington Ave. No.
Minneapolis 1, Minnesota
FEderal 8-6753
TWX: MP969

CIRCLE 112 ON READER-SERVICE CARD

Expanded-Scale Voltmeters Feature High Accuracy

Voltron's Expanded Scale A.C. & D.C. Voltmeters are designed for those critical applications requiring ac-



curacies of ±0.5% or better . . . The expansion network consists of a Wheatstone bridge. Two of the bridge elements are linear. If the IR drop across these elements is plotted against E, Curve 1 is obtained. One element is non-linear, and yields Curve 2. Thus the bridge is balanced at only one value of voltage, E_o. For any other value an error signal is obtained which is applied to a conventionl d'Arsonval type meter movement. Resistor R_1 is added to bring the bridge to balance at the desired low voltage value, and resistor R_2 is added to bring the meter deflection to maximum at the desired high voltage value. In A.C. voltmeters, a rectifier is added . . . (*From 4-page Bulletin* 601, *Voltron Products, Inc.*, 1020 *S. Arroyo Parkway, Pasadena, Calif.*)

FOR THIS LITERATURE CIRCLE 217 ON READER-SERVICE CARD

TRI-R *Electronic* THERMOMETER

THERMISTOR TYPE

- ***RAPID*** . . . Read temperature in seconds
- ***ACCURATE*** . . . ±½% of scale range
- ***RANGES*** . . . From −35 to +150°C.
- ***DIRECT READING*** . . . In °C. and °F.
- ***REMOTE READING*** . . . Leads to 1000 feet
- ***LOW COST*** . . . Priced from $72.00
- ***STABLE*** . . . Mercury cell battery models, regulated line operated models
- ***PROBES*** . . . Interchangeable and special for human, animal, laboratory use

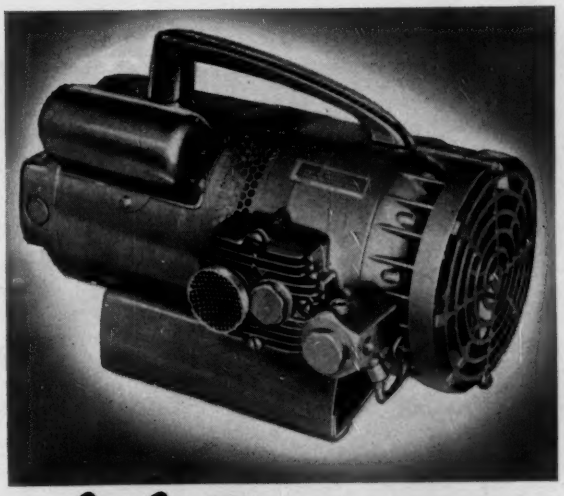
For Thermometer bulletin write Dept. K 51

TRI-R INSTRUMENTS

Developers of Electronic and Mechanical Instruments for Scientific Research

144-13 JAMAICA AVENUE, JAMAICA 35, N. Y.

CIRCLE 114 ON READER-SERVICE CARD



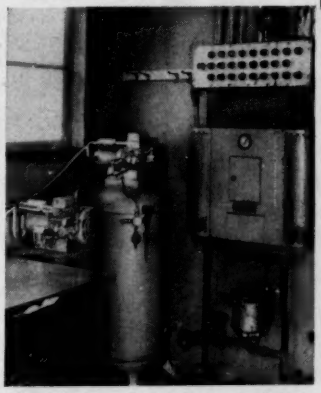
Oil-Free AIR FOR INSTRUMENTATION

For instrument control with compressed air, patented B&G Oil-less Compressors offer outstanding, exclusive advantages.

They deliver air *completely oil-free!* Carbon-graphite piston rings and skirts need no lubrication; bearings are grease-packed and sealed for life. Numerous design and construction features assure dependable delivery of cleaner, cooler, drier air and smoother operation.

B&G Oil-less Compressors can be located at the site of the control, eliminating long pipe lines which may contaminate the air with dirt and condensation.

Available in 58 models... portable, tank mounted, motor and gas-engine driven, 1/12 to 3/4 H.P., up to 6.57 CFM, up to 190 psi. Vacuum: 27.5".



Typical application to air drier

MINIATURE!

1/12 H.P. Oil-less Motor Compressor and Vacuum Pump

Fits in the palm of your hand, yet delivers much more free air than any current design of the same horsepower. It is capable of continuous operation at pressures up to 65 psi.—has infinite applications for instrument control, process agitation and motive power.

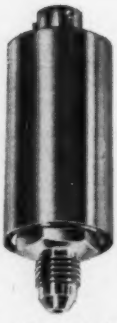
Oil-less **AIR COMPRESSORS**

BELL & GOSSETT COMPANY

Dept. GQ-84, Morton Grove, Illinois

CIRCLE 115 ON READER-SERVICE CARD

A Transducer Two Years Ahead of its Time



A completely new patented pressure sensor concept has been utilized in Servonic's new, low pressure L-96 Transducer. This miniature potentiometer-type unit withstands vibration levels in excess of 35 g's with less than 1% error. Two separate sets of aneroid capsules attached to opposite ends of a driving frame are utilized in the design. One set senses the driving media while the second can be evacuated for an absolute pressure reference, or vented to the atmosphere for gage measurement.

Pressure changes are transmitted through a unique, frictionless, metallic belt linkage system to position the wiper of the precision potentiometer. The fluid filled interior dampens vibration effect, provides long life and minimizes electrical noise. The unit is so insensitive to vibrations, extended dwells are allowed at any vibration frequency. Besides its excellent vibration characteristics, the L-96 has a temperature range of −65° to 275° F and a range of 0-15 to 0-350 psia or g.

For additional information about the wide pressure ranges and mounting configurations available in the L-96, write:

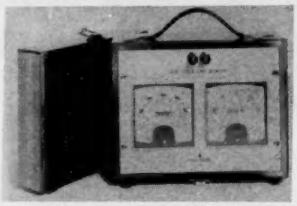
SERVONIC INSTRUMENTS, INC.

Manufacturers of pressure transducers, pressure switches, rectilinear potentiometers and slip ring assemblies.

1644 WHITTIER AVENUE, COSTA MESA, CALIFORNIA

CIRCLE 116 ON READER-SERVICE CARD

PORTABLE PRECISION METERS



New 400-cycle Line Monitor in the Shop-Lab line employs two expanded scale meters, one to measure frequency and the other voltage, with accuracy of 0.05% for the frequency meter, and 0.5% for the voltmeter. Carrying case permits any combination of meters up to four as required. Bulletin 609.—*Voltron Products, Inc.*, 1020 *So. Arroyo Parkway, Pasadena, Calif.*

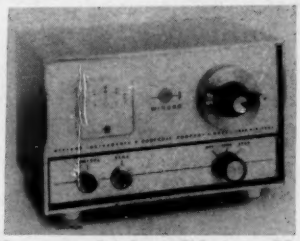
CIRCLE 269 ON READER-SERVICE CARD

MINIATURE SCOPE

New Miniature Oscilloscope, PRIMER-SCOPE, Mark I, weighs less than six pounds. Main component is a special 3" Rayonic cathode ray tube, incorporating an integral magnetic shield to prevent stray or spurious pickups. Accelerating potential is approximately 840 v.—*Waterman Products Co.*, 2445 *Emerald St., Phila.* 25, *Pa.*

CIRCLE 270 ON READER-SERVICE CARD

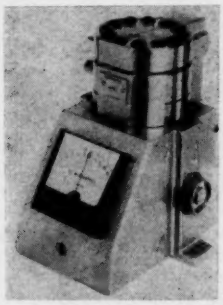
DIGITAL TEMP CONTROLLER



New completely solid-state Model 4050 Digitrol, is a digital, set-point, on-off temperature controller. Input is a 500-ohm platinum resistance transducer. Output is a set of relay contacts which can be made to vary from 2 to 15 amp at 115 vac. Range is 0 to 2000°F. Temperature differential between on and off is less than 2.5°F over the entire range; repeatability is ±2.5°F, resolution is ±0.5°F. —*Winsco Instruments & Controls Co.*, 11789 *W. Pico Blvd., Los Angeles* 64, *Calif.*

CIRCLE 271 ON READER-SERVICE CARD

DIFF PRESS INDICATOR



New Differential Pressure Indicator is for balancing two interconnected pressure systems. Pressure rating is 12,000 psig, with resolution 0.05 psig full scale. Can also be used to seal the pressure fluid in the dead-weight gaging system against liquids and gases in the system under test, and indicates any pressure differential across this seal.—*Ruska Instrument Corp., 6121 Hillcroft Ave., Houston 26, Tex.*

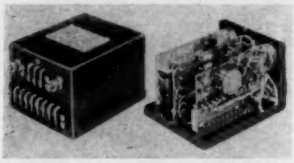
CIRCLE 272 ON READER-SERVICE CARD

EDGEWISE AC/DC METERS

New line of long-scale, 3" edgewise D-C and A-C Meters Model MDE-3, is available in a broad selection of d-c current (200 μamp and up) and voltage ranges, as well as in rectifier-type a-c styles. Mechanism is shielded so that the panel material has no influence on calibration. Can be mounted horizontally or vertically.—*Minneapolis-Honeywell, Precision Meter Div., Grenier Field, Manchester, N. H.*

CIRCLE 273 ON READER-SERVICE CARD

MINIATURE TRANSLATOR

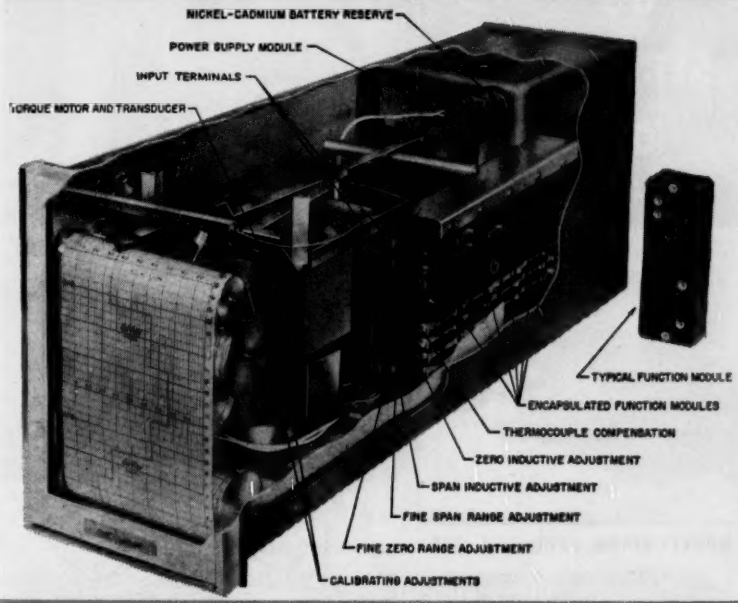


New transistorized Miniature DC-in DC-out Translator, Model A-801, for telemetering of displacement, pressure, etc with variable permeance or variable reluctance type transducers, features reflex multiple-function circuitry, good dynamic frequency response, high power output. Provides a gain stabilization of 167. Bulletin MTR-1.—*Physical Sciences Corp., 389 N. Fair Oaks Ave., Pasadena, Calif.*

CIRCLE 274 ON READER-SERVICE CARD

GENERAL KINETICS
DE VAR

NEW
MINIATURE
3 PEN RECORDER



- Potentiometer Recorder handles any mv. DC input from 0-5 mv.
- Receiver Recorder handles signals from 1V. or 100μa
- Solid state circuitry throughout — including unique transistor chopper
- Battery reserve eliminates costly down time
- No warm up time
- Inductive span and range adjustment — continuously variable
- Encapsulated function modules
- High torque pen drive motor — fast response without overshoot
- Full scale rectilinear writing with 1, 2, or 3 pens

The high performance characteristics of this recorder are unmatched by any other miniature recorder. In fact, some of the novel design features (e.g. DC input isolation and noise-free DC output signals) offer advantages found only in the most expensive full-size self-balancing potentiometric recorders. The DE VAR Recorder represents the ultimate in convenience, reliability, and flexibility in operation.

Write today for further information

DE VAR SYSTEMS INC.

494 GLENBROOK ROAD
GLENBROOK, CONNECTICUT
DA-4-1105

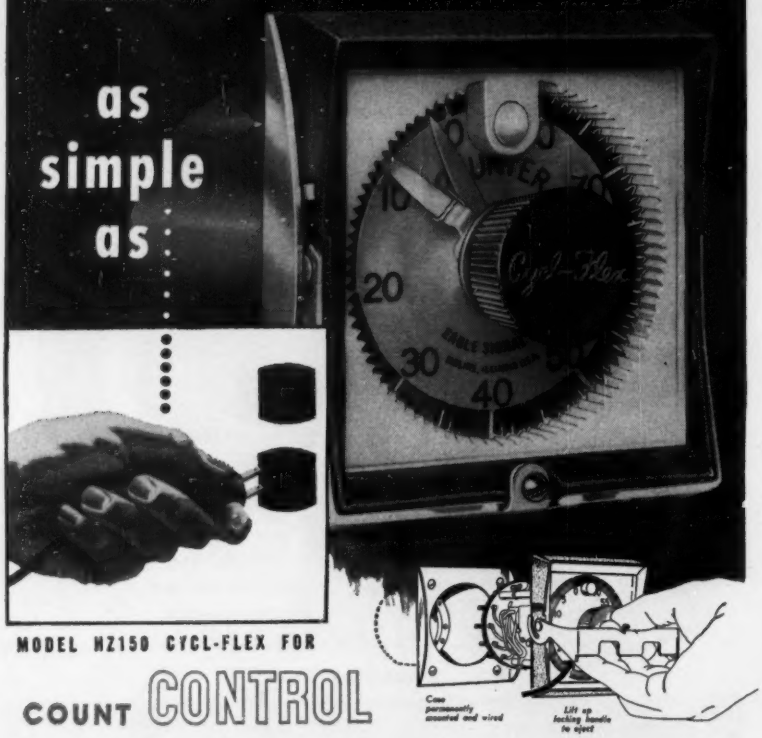
A DIVISION OF General Kinetics Corporation

CIRCLE 117 ON READER-SERVICE CARD

plugging-in EAGLE'S

NEW CYCL-FLEX COUNTER

as simple as .....



MODEL HZ150 CYCL-FLEX FOR

COUNT CONTROL

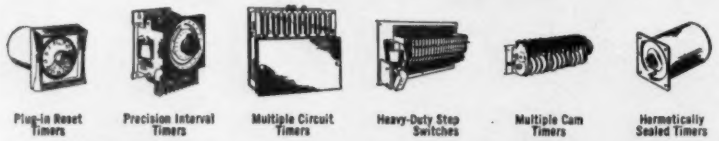
Yes, Eagle's New Cycl-Flex Plug-In Counter is as easy to adapt and change as its companion Cycl-Flex Timer. In fact, in mounting and in over-all appearance, they're exactly the same.

The New Cycl-Flex Counter does more than just count. A large variety of control circuits are yours by utilizing its one instantaneous switch and two delayed switches to control your machines or processes. Use this *count control* to automatically operate:

- The number of molding machine injection strokes
- Number of indexes on a rotary table
- Number of produced pieces before shutting off machine or conveyor

Write for Bulletin 725 or call your local Eagle Representative. He's listed in Sweet's Product Design File, Section 7d, or in Thomas Register.

SPECIFICATIONS • Count Range—80 counts • Electric Reset in ⅓ second • 400 counts per minute • 3-inch diameter quick setting dial with single knob • Switch rating—10 amps., 115 v., 60 cycle



BLISS

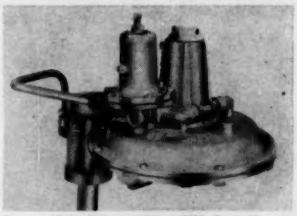
MANUFACTURERS OF THE MOST COMPLETE LINE OF INDUSTRIAL TIME-COUNT CONTROLS AVAILABLE

EAGLE SIGNAL COMPANY • Moline, Illinois

A DIVISION OF THE GAMEWELL COMPANY, AN E. W. BLISS COMPANY SUBSIDIARY

CIRCLE 118 ON READER-SERVICE CARD

PILOT-LOADED REGULATOR



New Model 173 High Pressure Regulator assembly and standard diaphragm combined with an 080R Pilot has an operating range of 10 to 1000 psig inlet pressure, and 2 to 20 psig outlet pressure. Capacity range from 2000 to 15,000 cfh of 0.6 gas, dependent upon pressure and orifice size combination. Available in 1" x 1" standard and ¾" x ¾" optional connection sizes. Standard orifice size is ¼" with optional orifice sizes of $\frac{1}{16}$", ⅜", and ½".—*Rockwell Mfg. Co., Meter and Valve Div., 390 North Lexington Ave., Pittsburgh 8, Pa.*

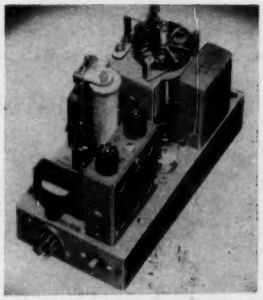
CIRCLE 275 ON READER-SERVICE CARD

TEMPERATURE SENSOR

New Model 177A resistance Temperature Sensor for nuclear applications measures absolute or differential temperature in the −70° to 300°C range. Withstands radiation level of 500 rad-hour or a total exposure of 5 x 10^7 rad, 1 Mev average. Meets requirements of MIL-T-2867B, Type RM.—*Rosemount Engineering Co., 4900 W. 78 St., Minneapolis 24, Minn.*

CIRCLE 276 ON READER-SERVICE CARD

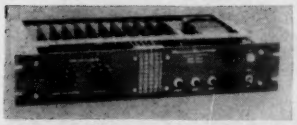
DIGITAL DECODER



New RPD-620 Digital Decoder employs the Model 49 HS Selector and matched electronic circuits to receive and decode 'interrupted tone" signals from any voice channel. Works on wire lines carrier, microwave, or radio circuits. Any code can be set or changed in a few seconds without tools. Bulletin PT-301A.—*Secode Corp., 555 Minnesota St., San Francisco 7, Calif.*

CIRCLE 277 ON READER-SERVICE CARD

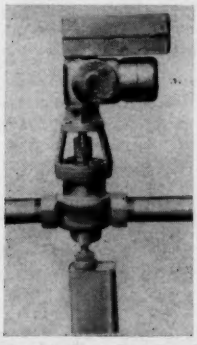
PRESET TIMER



New solid-state Preset Timer, Model 855-6, operates directly with Eldorado solid-state scalers and with other makes. Features two interchangeable time bases—10 kc crystal controlled oscillator, and 60 cps line. Time bases are easily changed by inserting plug-in cards. Five-digit neon readout expresses elapsed time in multiples of tenths of a second for the 60-cps time base, and multiples of one hundred thousandth of a minute for the 10-kc time base.—*Eldorado Electronics, 2821 Tenth St., Berkeley 10, Calif.*

CIRCLE 278 ON READER-SERVICE CARD

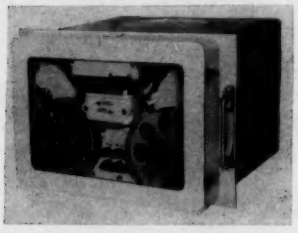
LIQUID SAMPLER



New Liquid Sampler for line fluid can be operated either manually or automatically on any pipeline regardless of pressure. Sample is taken at line pressure and stored in the container at atmospheric pressure. Bulletin 103.—*ARCCO Instrument Co., Inc., 7144 E. Condor St., Los Angeles 22, Calif.*

CIRCLE 279 ON READER-SERVICE CARD

TAPE READER



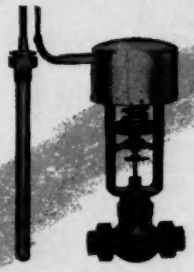
New Type 271 Tape Reader (to MIL-E-4970 and MIL-1-26600) is for slide or conventional mounting within a special console or standard rack. Reading speed is up to 300 characters/sec, with fully synchronous operation possible up to 220 characters/sec. Fast advance/rewind is provided at 1000 characters/sec. With the exception of the clock pulses all data logic is NRZ in nature.—*Ferranti Electric Inc., Industrial Park No. 1, Plainview, L. I., N. Y.*

CIRCLE 280 ON READER-SERVICE CARD

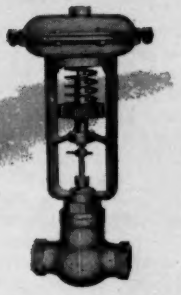
The Rugged, Efficient, Thrifty Line of

"WORK HORSE" CONTROLS

1110 FultroMatic . . . complete temperature control system in one air-actuated package: temperature controller, pneumatic control valve, positive valve positioner.



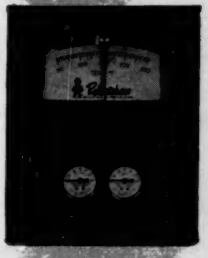
1004 Series . . . closest temperature control in the self-ops field. Available in 40° adjustment ranges from −35°F to +425°F. (Plus 8 other styles.)



CV Series . . . diaphragm- or bellows-actuated control valves for precise control of fluid flow in commercial or industrial applications. Pneumatic or hydraulic operation.

They look rugged, they *are* rugged . . . yet every Robertshaw control is designed for *performance* first. Plant engineers in leading industries continually specify Robertshaw for workhorse controls that stay on the job year after year with higher efficiency, lower maintenance.

Get the facts on dependable, moderate priced Robertshaw controls for your particular field. Ask for catalog A-AL.



1150 Series . . . an indicating pneumatic controller with greatest field serviceability; proportional action (5% to 200%), automatic reset, fully compensated thermal system.

1135 FultroPilot . . . for positive remote control through air signal to control valve, damper actuator, etc., from fast-response thermostat.

Robertshaw

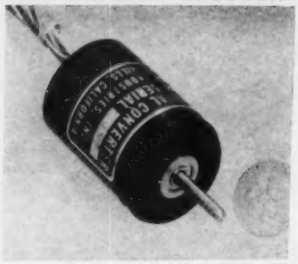
MR. CONTROLS

Robertshaw-Fulton Controls Company

FULTON SYLPHON DIVISION • KNOXVILLE 1, TENNESSEE

CIRCLE 119 ON READER-SERVICE CARD

SHAFT ANGLE ENCODER



New miniaturized eight-bit Shaft Angle Encoder, Model AD11-08S, is less than 1.4" long and weighs only 1.8 oz. including silicon isolation diodes and 15" of wire leads. Moment of inertia is 0.0026 oz-in^2, and driving torque is less than 0.3 oz-in. Resolution is one part in 256 equal to 1.4 degrees of shaft rotation, with an absolute conversion error of less than $\pm\frac{1}{4}$ of the least significant digit, or 21 minutes of arc.—*Litton Systems, Inc.*, 5500 *Canoga Ave., Woodland Hills, Calif.*

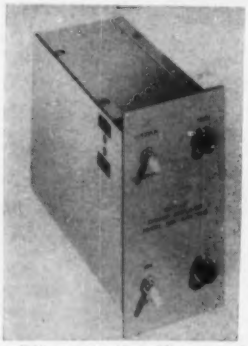
CIRCLE 281 ON READER-SERVICE CARD

OPTICAL TACHOMETER

New Multi-Probe is a self-contained instrument consisting of a photo-transistor, light source, associated amplifier circuitry, and battery power supply, which accurately senses intricate vibrations of test articles as required in new complex-wave environmental tests; measures mechanical shaft rotation 120,000 rpm; and senses frequency of vibration and relative amplitudes: 0 to 20 kc (min.); etc. Bulletin gives details.—*Optomechanisms Inc.*, 216 *E. Second St., Mineola, L. I., N. Y.*

CIRCLE 282 ON READER-SERVICE CARD

ELECTROSTATIC AMPLIFIER



New Electrostatic Charge Amplifier, Model 565, for use with piezoelectric accelerometers converts the electrostatic charge signal from a natural quartz crystal transducer to a voltage signal, compatible with the input requirements of oscilloscopes, recorders, and telemetering equipment. Bulletin 142261.—*Kistler Instrument Corp.*, 15 *Webster St., North Tonawanda, N. Y.*

CIRCLE 283 ON READER-SERVICE CARD

here's a tip* on thermocouple performance

* The Conax tip — highest rate of response, maximum accuracy, minimal downtime

1. In ungrounded junctions, maximum rate of response is achieved through maintenance of true cylindrical sections. Well closures are the same thickness as sheaths. (Grounded junctions also provided.)
2. Eliminates oxidation and danger of collapse by isolating the thermocouple in densely compacted insulation that completely fills the area . . . prevents vibration damage.
3. Eliminates corrosion and contamination potential arising from the use of fluxes through exclusive Conax electrical welding techniques.

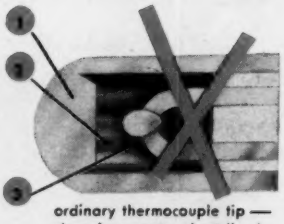
Find out how little it costs to get CONAX quality

conax con-O-clad

MINERAL-INSULATED THERMOCOUPLES

If you "X-RAYED" your thermocouples would you find these costly hazards?

1. Plug and ball welds, the mark of ordinary thermocouples mean slow response. 2. Air gaps create three dangers: — Oxidation that leads to thermocouple breakdown; sheath tip collapse under pressure; vibration damage to thermocouple tip. 3. Torch welding of hot junctions and well closures requires fluxes which corrode metal and contaminate insulation.



ordinary thermocouple tip — slow, inaccurate, short-lived.

TAKE A TIP — GET ALL THE FACTS ON:

CON-O-CLAD... ask for catalog 300

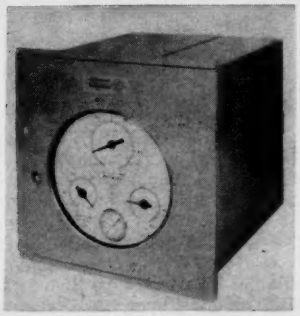
THERMOCOUPLE ASSEMBLIES... ask for catalog 1890

ELECTRODE GLANDS... ask for catalog 960

conax CORPORATION • 2300 WALDEN AVE., BUFFALO 25, N.Y.

CIRCLE 120 ON READER-SERVICE CARD

DIFF CONDUCTIVITY METER



New Type RID Differential Conductivity Meter measures and transmits (to a remote recorder) difference in solution conductivity at any two locations. Incorporates two complete and independent self-balancing a-c Wheatstone bridges. Both 0-100 mv dc, and 3-15 psig air transducers can be provided to transmit instrument readings to remote potentiometer or pneumatic recorders or recorder-controllers.—*Industrial Instruments Inc., 89 Commerce Rd., Essex County, Cedar Grove, N. J.*

CIRCLE 284 ON READER-SERVICE CARD

DUAL TIMER

New Dual-Trol comprises two timers operating in sequence and enables accurate control of electrical load for pre-determined period, while allowing pre-set timed interruption. Modules range from minimum time cycle and dial calibration of 1/10 sec with maximum time cycle of 6 sec to minimum time cycle of 3 min and maximum time cycle of 3 hours.—*Industrial Timer Corp., 1407 McCarter Highway, Newark 4, N. J.*

CIRCLE 285 ON READER-SERVICE CARD

DEVIATION ADAPTER

New A41A/1 Fluctuation Adapter computes the magnitude of fluctuation of any process variable, continuously reading a fluctuating 0.000-to-0.500 vac input from any Swartwout Autronic primary transmitter, computes the magnitude of fluctuation, and transmits a signal proportional to the magnitude to any Autronic controller. —*Swartwout Div., Crane Co., Hooksett Industrial Park, Manchester, N. H.*

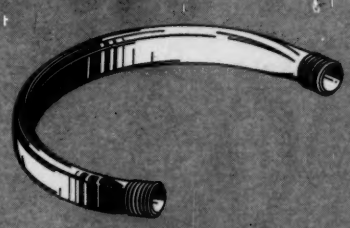
CIRCLE 286 ON READER-SERVICE CARD

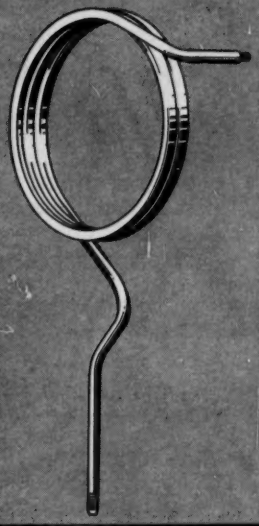
HEISE GAUGES

Corrosion Resistance

IN ULTRA HIGH PRESSURE INSTRUMENTS

Modern laboratory applications frequently require resistance to corrosive and semi-corrosive fluids as well as peak performance in ultra high pressure ranges. Heat treated 403 Stainless Steel, in an exclusive weldless Bourdon tube, provides superior service under the most critical conditions. Heise Gauges are frequently specified for use with mercury as a pressure medium.





0.1% F.S.R. Accuracy is guaranteed at pressures up to 100,000 p.s.i. by the Heise Multi-coiled Tube. This stainless steel tube is a weldless one piece element which completely eliminates all internal connections.

Premium instrumentation requires Heise Gauges.

Dial Sizes	FULL SCALE READING (P.S.I.)						
	0-15 to 0-5,000 inclusive	Over 0-5,000 and including 0-20,000	Over 0-20,000 and including 0-30,000	0 to 40,000	0 to 50,000	0 to 75,000	0 to 100,000
8½"	$183.50	$205.50	$238.50				
12"	$209.50	$231.50	$264.50	$275.50	$286.50	$336.50	$386.50
16"	$255.50	$277.50	$310.50	$321.50	$332.50	$382.50	$432.50

DELIVERY — 2 WEEKS FOR MOST RANGES — PRICE F.O.B. NEWTOWN

Request Catalog for SPECIAL FEATURES

HEISE BOURDON TUBE COMPANY, INC.

BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 121 ON READER-SERVICE CARD

NEW!

ERIE *Instrumation*®

Model 725A

220KC UNIVERSAL COUNTER/TIMER

$895

Only ERIE produces an instrument with all of these quality features as standard at no extra cost:

- IN-LINE NIXIE READOUT
- TRIGGER LEVEL CONTROLS —100V to +100V
- 220KC OPERATION
- 50 MILLIVOLT SENSITIVITY
- 5¼" RACK PANEL HEIGHT
- TRUE MODULAR CONSTRUCTION

In addition to these features, many of which are usually offered as options at additional cost, the Model 725A is an outstanding quality instrument. It accurately counts cyclic or random electrical events and precisely measures frequency, period and time intervals. NIXIE readout is available in five or six decades.

Model 725A is part of the newly designed 700 series of counter/timers. The panels have been planned for simplicity of operation and to reduce the opportunity for operator error. They are available for either rack mounting or in a heavy gauge aluminum case with carrying handles, where portability is desired.

Considering quality, flexibility, performance and price, the Model 725 is your best instrument for production or laboratory use. Why not send for complete technical information today.

Quality Where It Counts
ERIE *Instrumation*®

***ERIE-PACIFIC** manufactures a complete line of digital counting, timing and control instruments and systems for military or commercial use.*

ERIE PACIFIC, DIVISION OF ERIE RESISTOR CORPORATION

12932 S. Weber Way, Hawthorne, California

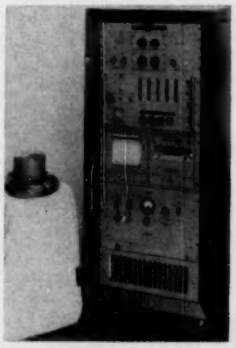
CIRCLE 122 ON READER-SERVICE CARD

NIXIE TUBE

New series of NIXIE Indicator Tubes features a flattened tube face and cutaway anode which permit higher positioning of the cathode numerals. These changes have increased the viewing angle of the tubes from 90° to 160°. Three new types are available: Standard type B5092; Type B6091, a new Super sized tube; and the completely new Large size tube, which has 1⅜" characters and is for viewing to 60 ft.—*Burroughs Corp., Electronic Tube Div., Plainfield, N. J.*

CIRCLE 287 ON READER-SERVICE CARD

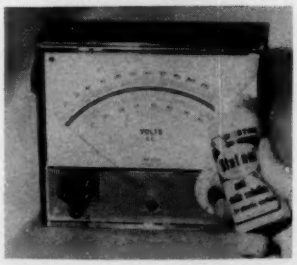
MAGNETOMETER



New V-4931 Modular Station Magnetometer, operating on proton free precession principle, measures absolute value of earth's total magnetic intensity in cycles from 3 to 60 sec, indicates value proportional to absolute field accurate to 8 parts per million. —*Varian Associates, Instrument Div.,* 611 *Hansen Way, Palo Alto, Calif.*

CIRCLE 288 ON READER-SERVICE CARD

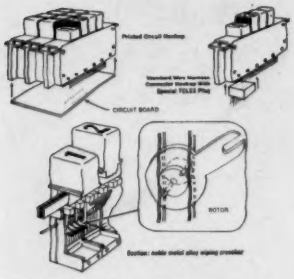
ANTI-STATIC FLUID



New Statnul anti-static fluid provides thin transparent coating which drains off static electricity from plastic-faced instruments. In contrast to other available anti-static agents, Statnul has remained effective in sustained atmospheres of 2% relative humidity.—*Daystrom, Inc., Weston Instruments Div.,* 614 *Frelinghuysen Ave., Newark* 12, *N. J.*

CIRCLE 289 ON READER-SERVICE CARD

ARRAY SWITCH



New 96-button General Purpose Pushbutton Switch with modular construction permits use of two or more pushbuttons in any array, is custom built for switching input to a computer. Eliminating need for a relay, Telex switch is momentary or interlocked, and can be remotely cleared. Each pushbutton can represent an 8-PST switch or a 4-DPDT switch.—*Telex, Inc., Dept. KP, Special Products, Div.,* 1633 *Eustis St., St. Paul* 1, *Minn.*

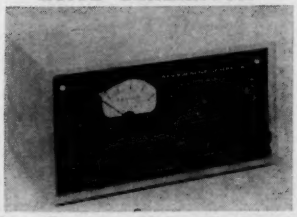
CIRCLE 290 ON READER-SERVICE CARD

SAMPLE CHANGERS

New FD-1 (1") and FD-2 (2") Flow Counters in window or windowless models operate in either geiger or proportional regions, require no change of center wire. Unique plug-in construction; operation in many counting modes. Bulletin SC-100.—*Tracerlab, Inc.,* 1601 *Trapelo Rd., Waltham* 54, *Mass.*

CIRCLE 291 ON READER-SERVICE CARD

NOISE GENERATOR



New Random Noise Generator, Model 811B, is source of "white noise." Incorporates internal pink noise filter which gives equal noise power per octave from 20 cps to 100 kc. Output voltage on the pink noise range is 1.5 v rms and 2.5 v on all other ranges. Covers frequency spectrum from 2 cps to more than 1.5 mc.—*H. H. Scott Inc., Instruments Div., Dept. P,* 111 *Powdermill Rd., Maynard, Mass.*

CIRCLE 292 ON READER-SERVICE CARD

TIME FOR YOU

TO DESIGN YOUR OWN TIMING SYSTEM WITH EECO'S DO-IT-YOURSELF COMPONENTS

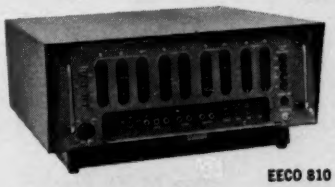
Now instrumentation engineers and test range management can build up their own precision timing systems with the convenience and economy of standardized, compatible, *all solid state,* off-shelf components. All standard time code formats available. Frequency stability, 3 parts in 10^8/day. Every EECO product is realistically priced for tight budgets. Prices include system design consultation by the leading developers of timing and synchronization instrumentation.

TIME CODE GENERATORS

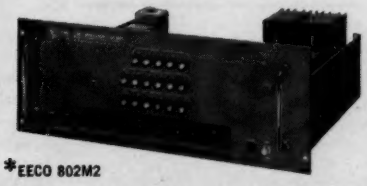
Model Number	Serial Code Format	Time Indication	Code Frame Length (SEC)	Code Seen Rates (PPS)	Code Carrier Frequency (CPS)	Auxiliary Pulse Rates (PPS)	Price (f.o.b. Santa Ana)
EECO 801	24-Bit, 24-hour, BCD	hours, minutes, seconds	1	25, 50, 100	1000	100K, 10K, 1K, 100, 50, 25, 10, 1	$7500
EECO 802 (Eglin AFB and Patrick AFB)	17-Bit, 24-hour, Binary	hours, minutes, seconds	1	20, 100	1000	100K, 10K, 1K, 100, 20, 10, 1	$7000
	13-Bit, 24-hour, Binary	hours, minutes, ¼ minutes	15	1	1000		
* EECO 802M2 (Atlantic Missile Range)	17-Bit, 24-hour, Binary	hours, minutes, seconds	1	20, 100	1000	100K, 10K, 1K, 100, 20, 10, 1	$7000
			20	1			
EECO 803	20-Bit, 24-hour, BCD	hours, minutes, seconds	1	25	250	None	$7500
EECO 804	20-Bit, 24-hour, BCD	hours, minutes, seconds	1	25	100 (mixed with 1000)	1 1pp10s 1ppm	$7925
EECO 810	36-Bit, 365-day, BCD (4 extra bits available for identification data)	days, hours, minutes, seconds	1	100	1000	None	$10,100
EECO 810M1 (IRIG Member C Format Modified)	23-Bit, 365-day, BCD (4 extra bits available for identification data)	days, hours, minutes, seconds	60	2	1000	10K, 1K, 100 10, 1, 1ppm, 1pphr	$10,100

Model Number		Price (f.o.b. Santa Ana)
EECO 860	**Neon Distribution Amplifier.** Accepts up to 3 pulse-width modulated signals from a time code generator to provide signals to drive camera neon lamps in remote sites.	$2500
EECO 861	**Relay Driver.** Accepts up to seven separate pulse trains or pulse-width modulated codes from a time code generator. Seven separate mercury-wetted relay contact closures to control external equipment.	$1200
EECO 863	**Line Driver** for transmitting 12 channels of carrier modulated timing signals over long distances.	$1975
EECO 27096	**Scanner Unit.** Accepts outputs from the EECO 802M1. Produces two 17-bit modified time-of-day codes in the format of the Atlantic Missile Range and one pulse rate output.	$5775

Compatible automatic magnetic tape search equipment is available for operation with each EECO time code generator.



EECO 810



*EECO 802M2

SEND FOR TIMING EQUIPMENT FILE 401, TAPE SEARCH FILE 201.

Electronic Engineering Company *of California*

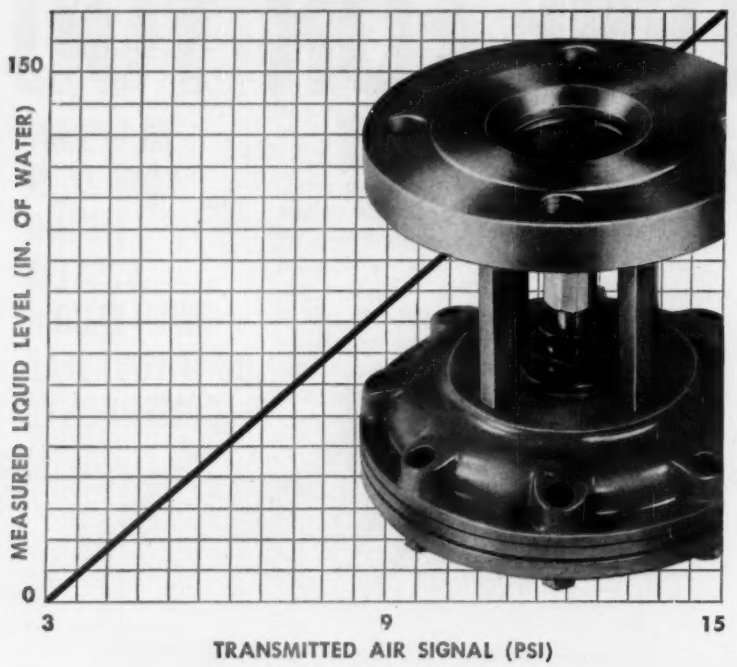
1601 East Chestnut Avenue • Santa Ana, California • Kimberly 7-5501 • TWX: Santa Ana Cal 5263

MISSILE & AIRCRAFT RANGE INSTRUMENTATION • DIGITAL DATA PROCESSING SYSTEMS • TIMING SYSTEMS • COMPUTER LANGUAGE TRANSLATORS • SPECIAL ELECTRONIC EQUIPMENT

EE 1-29

CIRCLE 123 ON READER-SERVICE CARD

TYPICAL PERFORMANCE CURVE OF MODEL "P" TRANSMITTER



LOW COST

PRESSURE AND LIQUID LEVEL TRANSMITTER WITH QUALITY FEATURES FOR DEPENDABLE OPERATION

The Conoflow Model "P" Transmitter is a low cost, rugged instrument which measures pressure and liquid level and transmits a *linear* 3-15 psi signal to standard receiver elements. Incorporates many features not found in more expensive devices for guaranteed dependable operation.

Safety—Process liquids and gases cannot back up into air lines and damage costly instruments. This is assured by the complete separation of measuring diaphragm from pneumatic pilot.

Simple Installation—The Model "P" can be mounted either horizontally or vertically on open or closed vessels. No dip tubes, floats or other mechanical devices are required inside the tank.

Long Life—Only the corrosion-resistant *Inconel X* diaphragm is exposed to the measured material. Preformed diaphragm will not work-harden or fatigue; withstands pressures to 500 psi and temperatures to 450°.

Versatile—Can be used for practically any service; ideal for viscous fluids or materials with solids in suspension; also for flowing bulk materials such as pigments, flakes, etc.

Choice of Ranges—Available for measuring ranges as low as 0 to 100" of water and pressures as high as 250 psi. Ranges can be changed in the field.

Specifications—New Bulletin P-36-1 contains complete specifications on the Conoflow Model "P" Transmitter. Write for your copy today or ask for a quote. No obligation. Conoflow Corporation, 2100 Arch Street, Philadelphia 3, Pa.

CC-1003

CONOFLOW CORPORATION
FOREMOST IN FINAL CONTROL ELEMENTS
SUBSIDIARY WALWORTH

CIRCLE 124 ON READER-SERVICE CARD

PRESSURE TRANSDUCER

New all-stainless 1¼"-dia Pressure Transducer, Type 78-C, uses welded N1 Span C pressure element linked inductively to differential transformer. High continuous output, available in ranges from 0-5 to 0-350 psi, temps from −115° to +500°F.—*United Aero Products Corp., Columbus Rd., Burlington, N. J.*

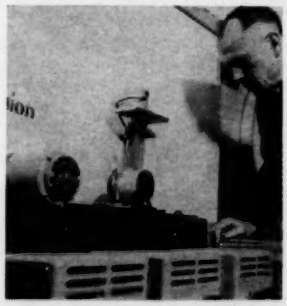
CIRCLE 293 ON READER-SERVICE CARD

RATE CONTROL

New Digital Comparator, which provides high accuracy control of speed, flow rate, pressure or any other function that can produce a proportional pulse rate or frequency, is a form of beat frequency generator that delivers a series of beat pulses to effect a corrective action proportional to the error. Typical application is for multiple component on-line blending. Uses solid-state components and printed-circuit construction.—*Jordan Controls, Inc.*, 3235 *W. Hampton Ave., Milwaukee 9, Wis.*

CIRCLE 294 ON READER-SERVICE CARD

SLO-SYN SERVO MOTOR



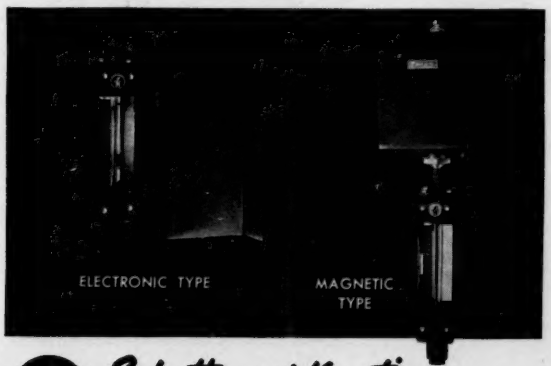
New Slo-Syn Synchronous Motor which can stop, start, or reverse itself up to 400 times/sec is included in an automation system with a memory stored on tape which transmits commands through an electronic translator circuit (Pulse-to-Step) to the mechanical muscle (Slo-Syn). System can be used for automatic control of machine tools and precision grinding equipment, parts positioning on assembly line, sampling of memory discs, camera focusing and positioning, etc.—*Superior Electric Co.*, 83 *Laurel St., Bristol, Conn.*

CIRCLE 295 ON READER-SERVICE CARD

ALARM ROTAMETERS

SIGNAL ABNORMAL FLOW RATES

SK Alarm Rotameters accurately measure fluid rate of flow—activate a light or alarm device, start or stop a pump, motor, control unit *in case of abnormal flows*. They are accurate, economical, dependable. Get details in new Bulletin 18A.



Schutte and Koerting COMPANY
INSTRUMENT DIVISION
2225 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.
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CIRCLE 125 ON READER-SERVICE CARD

Rheology / Viscosity

Does the quality or cost of your product depend on its flow characteristics?

► A complete line of Epprecht Viscometers provide viscosity measurements in the laboratory or during processing with automatic control of viscosity.

► Measurements can be made at pressures up to 700 psi or in a vacuum at temperatures to 300° C.

For detailed technical information on Epprecht Viscometers write to Dept. DV-37.

J. W. FECKER DIVISION
AMERICAN OPTICAL COMPANY
6592 HAMILTON AVENUE • PITTSBURGH 6, PENNSYLVANIA

CIRCLE 127 ON READER-SERVICE CARD

MODEL DC-200AR

Accuracy	.01% ±5 μv of reading
Ranges	0-1000v DC
Long Term Stability	Better than .003%
Reference Stability	2 ppm/°C
Price	$985*

MODEL DC-100A

Accuracy	.03% ±5 μv of reading
Long Term Stability	Better than .01%
Reference Stability	3 ppm/°C
Price	$475*

CALIBRATION > STANDARDS

Self Calibrating DC Voltmeters

Now, in the Model DC-200AR Voltmeter, fine accuracy Voltage measurements with a 6 digit readout. Completely transistorized. This instrument and its companion DC-100A use ultra-stable Zener references. The stability, inherent in both these Voltmeters, make them essential to reliable laboratory and production testing. Only 3 watts of power at 117 VAC required. DC-100A available as a DC-100AR in rack mounting. *Write for detailed specifications or contact your local CSC representative.*

LOS ANGELES, SMITH-DIETRICH SALES COMPANY • SEATTLE-PALO ALTO, STANLEY ENTERPRISES • DENVER-SALT LAKE CITY, EMF ASSOCIATES • CHICAGO, LOREN P. GREEN & ASSOCIATES • WICHITA, LAWRENCE L. HILL • WALTHAM, MASSACHUSETTS, GEO. GOSTENHOFER & ASSOCIATES • SCHENECTADY, CHARLES A. WINICK COMPANY • NEW YORK CITY (MT. VERNON), GED ELECTRONIC SALES, INCORPORATED • PHILADELPHIA (LANSDOWNE), HOLDSWORTH & COMPANY • ARLINGTON, VIRGINIA, THE JAY COMPANY • ATLANTA-COCOA BEACH, SPECIALIZED EQUIPMENT COMPANY • CLEVELAND-DAYTON-DETROIT, ELECTRO SALES ASSOCIATES • EXPORT, FRAZAR & HANSEN, LTD.

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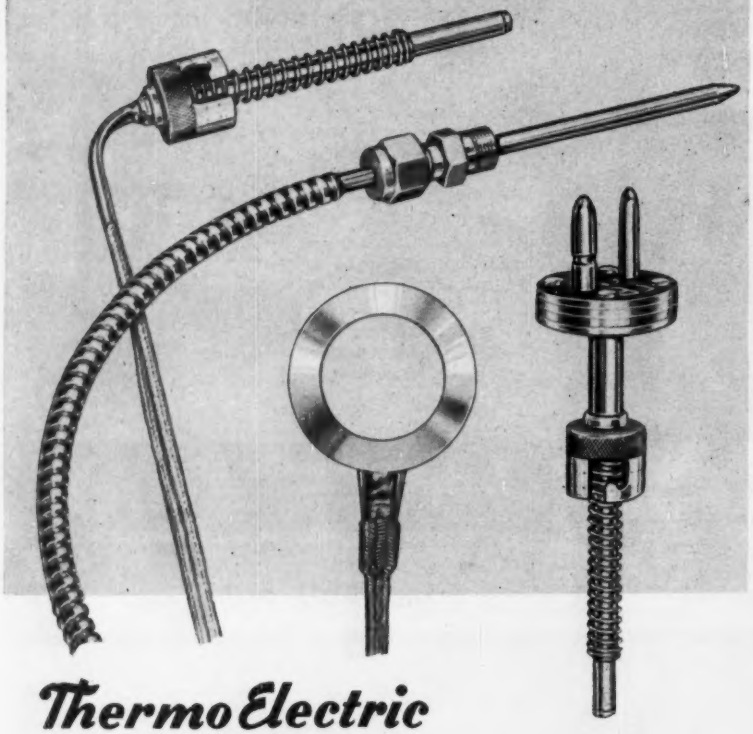
CIRCLE 126 ON READER-SERVICE CARD

Peak Performance—
economy on the job!



ThermoElectric
Miniature Thermocouples

You can obtain a Thermo Electric Miniature Thermocouple for peak performance and economy in almost every application! Those illustrated are available in a wide variety of sizes, standard thermocouple materials, adapt to many applications.

Protected thermocouples are extremely sensitive, give fast response to minute temperature changes. The measuring junction is welded or silver soldered to the tip of the thin-walled "Ceramo" metal sheath. Ideally used in corrosive liquids or gasses—and many pressure applications. For quick-coupling versatility, the spring-loaded bayonet-lock thermocouple is tops! You can use one "couple" at various depths with different adapters. With spring-loading, tip contact is always maintained. The bayonet type is highly sensitive, fast responding, for use in pump and engine cylinder heads, turbine housings, pipes, electric motors, generators, plastic extruders and molding machines.

Gasket Thermocouples measure surface temperatures in all sorts of stationary or moving machinery.

T.E. also produces stagnation, exposed junction and shielded thermocouples for use in air, gas or vaporous atmospheres.

write today for Bulletin 1256-12

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.

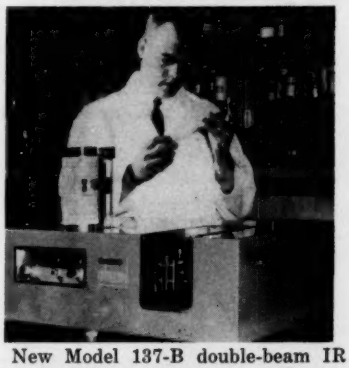
CIRCLE 128 ON READER-SERVICE CARD

PULSE GENERATOR

New line of solid-state Pulse Generating Equipment includes two Clock Pulse Generators and Programmed Pulse Generator Model 6200 (illustrated). The Programmed Pulse Generator features an internal pulse repetition rate of from 3 to 25 mc and with an external rates below 3 mc. Rise/fall times are less than six nanoseconds.—*Texas Instruments, Inc., Apparatus Div., Box 6027 Houston 6, Tex.*

CIRCLE 296 ON READER-SERVICE CARD

INFRARED SPECTROPHOTOMETER



New Model 137-B double-beam IR Spectrophotometer permits (and automatically records) complete 2.5-15 micron scan in 3 min (¼ time previously required) for analysis of organic compounds. Addition of fast speed optics triples output of instrument.—*Perkin-Elmer Corp., Norwalk, Conn.*

CIRCLE 297 ON READER-SERVICE CARD

REED RELAYS

New standard Dunco encapsulated reed relays are available with electrostatic shields surrounding glass switching elements and isolating reed contacts from stray electrical noise or random pickup of unwanted signals. In 1, 2, 4, 12 and 20 pole types; any or all poles shielded as specified.—*Struthers-Dunn, Inc., Pitman, N. J.*

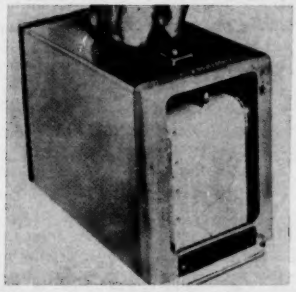
CIRCLE 298 ON READER-SERVICE CARD

GENERAL PURPOSE THERMOCOUPLE

New rugged, adaptable thermocouple for high temp and pressure applications—gas turbine and internal combustion engines, steam generators, oil and chemical processes, etc.—is supplied with high temp terminal block 1⅛" dia, and MgO insulated sheathed thermocouple elements. Available in all common calibrations and sheath materials in diameters from 0.062 through 0.250. Junctions supplied either grounded, ungrounded or exposed.—*Thermocouple Products Co., Inc., 729 N. Addison Ave, Villa Park, Ill.*

CIRCLE 299 ON READER-SERVICE CARD

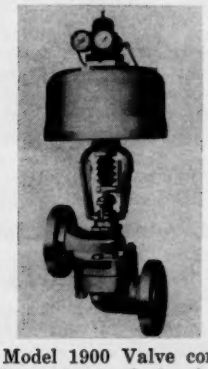
PORTABLE RECORDER



New fully transistorized battery-operated Potentiometer Recorder has chart driven by a clockwork motor with an 8-day movement. Standard chart speeds are ½ to 12 iph. Full scale deflection ranges are available between 0-5 mv and 0-100 mv. Overall accuracy is better than 0.5%. Dimensions are 7" x 5¼" x 10". Weight is 17 lb. Inkless wax paper is employed on a chart 3" wide.—*Instrument Corp. of Amer., 516 Glenwood Ave., Baltimore 12, Md.*

CIRCLE 300 ON READER-SERVICE CARD

SELF-DRAINING CONTROL VALVE



New Model 1900 Valve completely drains line and valve body of complex fluids, slurries, etc. which contaminate or harden in processing system. Connections: screwed 300 lb in ½"-2" sizes; flanged 150 lb, 300 lb in sizes ½"-6".—*Annin Co., Div. Worthington Corp., 1040 S. Vail Ave., Montebello, Calif.*

CIRCLE 301 ON READER-SERVICE CARD

Solve

HIGH TEMPERATURE

measurement problems beyond the scope of conventional pyrometers...

PYRO-650*

Fully Automatic Optical *Brightness* Pyrometer

If you have been using a manually operated optical pyrometer, but now need an instrument that operates continuously, and makes possible both recording and controlling, the PYRO-650 Automatic Optical Brightness Pyrometer is designed for you.

PYRO-650 measures temperature automatically and continuously over a wide range from 1200°F to 6300°F; 650°C to 3500°C. Since it is fully automatic, any possibility of human error is eliminated . . . reliability is assured. PYRO-650 makes rapid and accurate measurements . . . essential in physical property studies of exotic metals, cermets, graphites and refractories at high temperatures. PYRO-650 gives you a continuous, permanent record of measurement . . . important in short duration temperature studies and necessary where certification of temperature test data is a requirement.

The fully automatic PYRO-650 Optical Brightness Pyrometer makes use of industry's many years of technical knowledge and experience . . . and takes the next logical step beyond the manual optical pyrometer.

Write today for Bulletin No. 614, describing PYRO-650 in full detail.

*Trademark of Instrument Development Laboratories

IDL

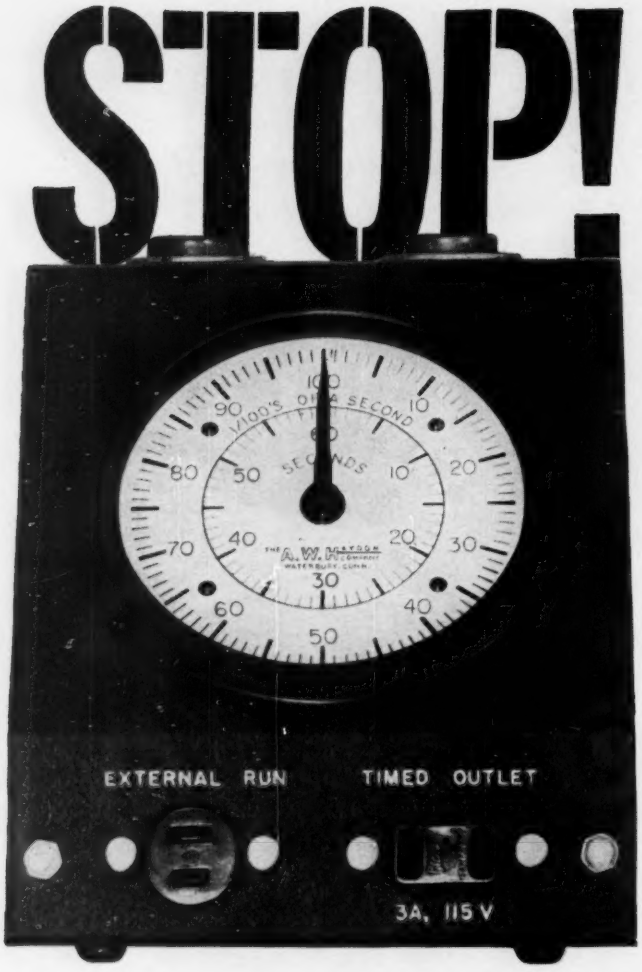
INSTRUMENT DEVELOPMENT LABORATORIES, INC.

Subsidiary of Royal McBee Corporation

MECHANIC STREET, ATTLEBORO, MASS.

Also manufacturers of PYRO-EYE® Two-color Optical Pyrometer

CIRCLE 129 ON READER-SERVICE CARD



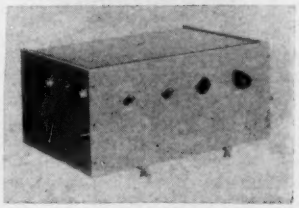
Look what happened when A. W. Haydon designed a new LABORATORY STOP CLOCK

You just won't find these features in any other stop clock. This versatile timer-of-all-work was designed by engineers who understand timers and timing...and who needed a precise time reference in their own work. **Timed outlet**—energized whenever clock runs, supplies 115V, 60 CPS, 3 amp to time and control external loads simultaneously...manually or automatically. **External Run Socket**—for remote running, using a control cable... manually or automatically (when wired into a system). **Clutchless timing mechanism**—needs no warm-up, make-ready or pre-start. Synchronous motor starts and drives instantly. No power consumed except during timing and reset. **Independent RUN and RESET** buttons for manual, local control. **Schematic diagram** and control circuitry silk-screened on bottom of housing for ready reference. ■ Bench type precision stop clocks are available with optional remote control for manual or automatic running and/or resetting. Clocks operate on commercial 115V, 60 CPS power; accuracy is ± 25 milliseconds. Low power drain: only 2 watts, timing. Sweep second scale calibrated in 10 millisecond increments; totalizer scale calibrated in seconds, up to 1 min. Sturdy instrument case requires only 4¼" square bench space. For complete specifications, write for Bulletin ET-702. Ask also about panel-mounting versions.

THE AWH HAYDON COMPANY
228 North Elm Street, Waterbury 20, Connecticut

CIRCLE 130 ON READER-SERVICE CARD

REPETITIVE SCAN



New Repetitive Scan Accessory permits Cary Spectrophotometer to operate unattended over preselected wavelength span. Useful for kinetic or other time base studies or for scanning series of similar samples. Can be installed on instruments already in the field.—*Applied Physics Corp., 2724 S. Peck Rd., Monrovia, Calif.*

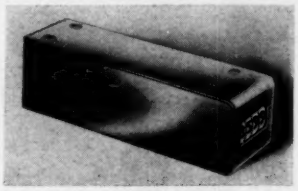
CIRCLE 302 ON READER-SERVICE CARD

SCANNER-MULTIPLEXER

New DC-112 Universal Module for counting, distributing, multiplexing, and scanning applications uses general-purpose BEAM-X switch, Type BX-1000, in conjunction with a frame grid pentode tube which performs the coupling function between successive modules. DC-115 Binary Decoder converts 1248 or 1224 binary-coded decimal information to decimal form. DC-113 Low Cost Counter operates at 1 kc and drives NIXIE indicator tubes directly.—*Burroughs Corp., Electronic Tube Div., Box 1226, Plainfield, N. J.*

CIRCLE 303 ON READER-SERVICE CARD

BEARING COUNTER



New 360° Bearing Counter featuring translucent figures designed specifically for high contrast ratio, registers ten tenths or one deg per rev of shaft. Operates at a speed of 600 indicated deg/min, and torque is one in-oz over a temperature range of −67° to 180°F.—*Veeder-Root Inc., 70 Sargeant St., Hartford 2, Conn.*

CIRCLE 304 ON READER-SERVICE CARD

5-MC LOGIC MODULES

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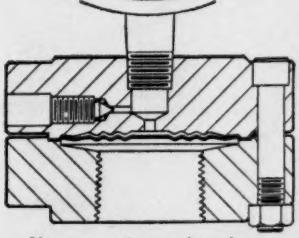

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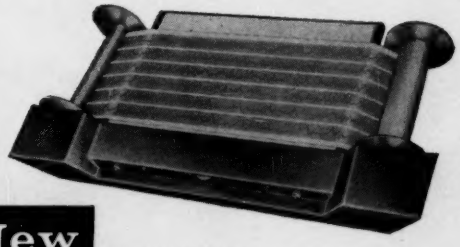

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Switch Differential	The switch differential is uniform throughout the entire range. Factory pre-set for any point between .2" and 10" W.C.
Switch Ratings	1 to 15 amps at 115 V AC dependent upon on-off switch differential.
Switch Types	N.O., N.C., or Double Throw — no neutral position.
Maximum Controlling Pressure	15 psi.
Size & Weight	7" lg. x 3⅜" diam. overall . . . weighs approximately 3 lbs.
Electrical Connection	½" NPT conduit opening in enclosure. Internally-located terminal block.
Pressure Connection	¼" female NPT.
Enclosure	Extruded aluminum case with black anodized finish.
Mounting	Directly mounted by the ¼" NPT brass female pressure fitting. Fitting material available in stainless steel for corrosive applications. Also wall mounted on specification.
Bellows	Seamless beryllium-copper or stainless steel bellows. Spring loaded to insure quick, accurate response under pressure or vacuum changes.

UNITED ELECTRIC ***manufactures a complete line of temperature, pressure, and vacuum controls. For information on modifying standard units or providing custom-built units, consult a UE application engineer. For additional data on pressure-vacuum controls, including the Type H9, request new catalog section #300.***

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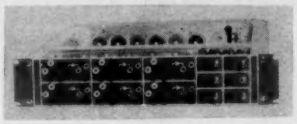
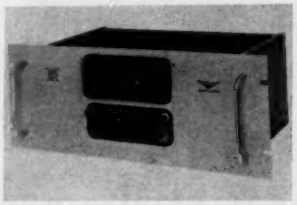
OPERATIONAL AMPLIFIERS



New Model C/06P/S/CO Stabilized Operational Six-Pack features front panel fixed patchbay, accommodates 6 pairs of plug-in amplifiers to provide 6 channels of high-gain drift-stabilized analog computation. Programming is accomplished by plugging in standard precision resistors and capacitors and interconnecting with standard patch cables.—*Embree Electronics Corp., West Hartford, Conn.*

CIRCLE 308 ON READER-SERVICE CARD

BIN/DEC CONVERTER



New Model 100 TBD Binary-to-Decimal Converter features automatic conversion, acceptance of positive or negative input information with negative or positive encoder interrogation, and a memory for command readout and hold. Standard readout is in-line NIXIE with four decades and a maximum count of 8191 (13 binary bits) with absolute accuracy. Has a self-test feature and display time from 0.2 to 6 sec.—*Erie Pacific Co., Div. of Erie Register Corp.*, 12932 *S. Weber Way, Hawthorne, Calif.*

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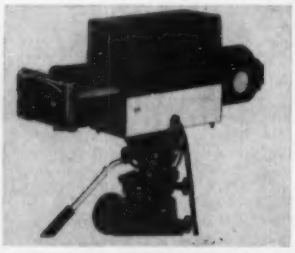
IMAGE CONVERTER CAMERA



New Image Converter Camera, "only complete diagnostic tool for instrumentation of high speed luminous transient events encountered in plasma physics, chemical kinetics and hypervelocity experiments," takes framed photographs at exposure times 3 to 200 millimicroseconds, 3-picture series at rates of ½ to 20 million exposures per second. Streak photographs at writing speeds of 4 to 1,000 mm/μsec.—*STL Products, Div. Space Technology Laboratories, Inc., Box* 95001, *Los Angeles* 45, *Calif.*

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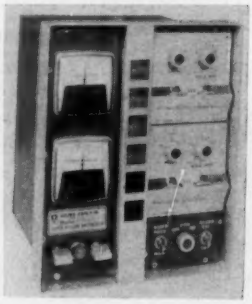
MONITOR-ANALYZER



New Series-18 transistorized plug-in Operation Monitors translate amplitude and frequencies of signals obtained by pickup devices attached to machines or processes into normal and off-normal indications. Signal levels and frequencies are shown on panel meters which can be calibrated in units of vibration displacement, velocity, acceleration, G's strain, peak strain, pressure, peak pressure, optical reflectivity, and sound levels, or frequencies. Frequency range is 2 cps to 10 kc.—*RayData Corp., Columbus, Ohio.*

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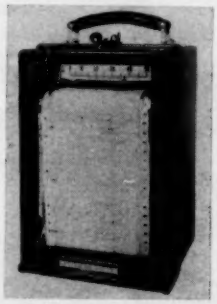
MICROAMMETER



New 50-microamp DC Microammeter (20,000 ohms/volt voltmeter) features operation on 120-v ac in a frequency range from 50 to 400 cps. Can be used overseas where 50-cps frequency is common, or in aircraft, which usually have 400-cps generator.) It can be ordered also to operate on 12-v battery power supply.—*Esterline Angus Instrument Co., Inc.*, 1201 *Main St., Speedway, Ind.*

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Valid only: in U.S. and Canada; if filled out completely; Until 8-1-61 **May 61**

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1	21	41	61	81	101	121	141	161	181	201	221	241	261	281	301	321	341	361	381	401	421	441	461
2	22	42	62	82	102	122	142	162	182	202	222	242	262	282	302	322	342	362	382	402	422	442	462
3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	323	343	363	383	403	423	443	463
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	324	344	364	384	404	424	444	464
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	325	345	365	385	405	425	445	465
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	326	346	366	386	406	426	446	466
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	327	347	367	387	407	427	447	467
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	328	348	368	388	408	428	448	468
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	329	349	369	389	409	429	449	469
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	330	350	370	390	410	430	450	470
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	331	351	371	391	411	431	451	471
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	332	352	372	392	412	432	452	472
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	333	353	373	393	413	433	453	473
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	334	354	374	394	414	434	454	474
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	335	355	375	395	415	435	455	475
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296	316	336	356	376	396	416	436	456	476
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297	317	337	357	377	397	417	437	457	477
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298	318	338	358	378	398	418	438	458	478
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299	319	339	359	379	399	419	439	459	479
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480

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IGS EVENTS

June 4-9
Ninth Annual ASTM Meeting on Mass Spectrometry, Hotel Sherman, Chicago, Ill. For information write Dr. George Crable, Gulf Research Center, Box 2038, Pittsburgh 30, Pa.

June 6-8
ISA Summer Instrument-Automation Conference & Exhibit, Royal York Hotel and Queen Elizabeth Hall, Toronto, Ont., Canada. For information contact Instrument Society of America, Wm. H. Kushnick, 313 Sixth Avenue, Pittsburgh 22, Pa.

June 6-8
Second National Congress on Environmental Health, School of Public Health, University of Michigan, Ann Arbor, Michigan. For information write H. E. Miller, Director, Continued Education, University of Michigan, Ann Arbor, Mich.

June 9-17
International Chemical Engineering Exposition and Congress ACHEMA, Frankfurt am Main, West Germany. For information write Chicago Section American Chemical Society, 86 East Randolph St., Chicago 1, Ill.

June 12
ISA-APCA Air Pollution Instrumentation Symposium (with the June 11-15 Annual Meeting of the Air Pollution Control Association), Hotel Commodore, New York, N. Y. For information write Meetings Manager, Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

June 13-16
Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich. For information write Meetings Manager, Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

June 15
Computer Conference on Business Languages, Allen Memorial Medical Auditorium of Western Reserve University, Cleveland, Ohio. (Admission by pre-registration only, before May 31, 1961.) For information write Jack Belzer, conference registrar, Western Reserve University, School of Library Sciences, Cleveland, Ohio.

June 19-23
Fifth Biennial Conference on Carbon, Pennsylvania State University, University Park, Pa. For information write Fifth Carbon Conference, Pennsylvania State University, Conference Center, University Park, Pa.

June 22-23
Eighth Annual Symposium on Computers and Data Processing, Elkhorn Lodge, Estes Park, Colo. For information write W. H. Eichelberger Denver Research Institute, University of Denver, Denver 10, Colo.

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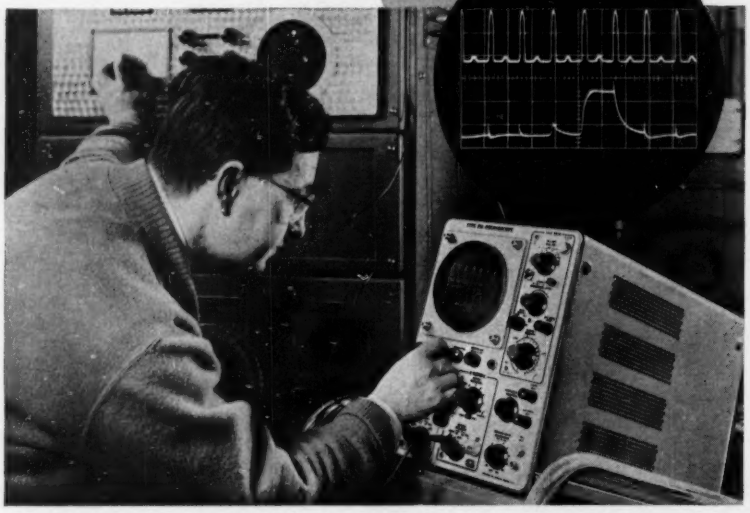
Tektronix DUAL-TRACE Oscilloscope

Used in *Development of* High-Speed Welder

New, high-speed, precision welder developed at MAXIM CONTROLS COMPANY utilizes a controlled gate pulse—rather than capacitance decay—for joining high-temperature alloy materials, such as those used in manufacturing structural "honeycomb" cores.

In development of this new welder the Tektronix Type 516 Oscilloscope was used for monitoring the time length of individual welds—since as many as six welds can be set to occur simultaneously or any number, sequentially—and for observing the constant amplitude and width of gate signals—thus assuring uniform bonds at speeds up to 2000 welds per second.



Adjusting pulse width and height of welding signal from newly developed Welding Control apparatus developed by MAXIM CONTROLS COMPANY, Portland, Oregon.

By observing the dual-trace display on the Tektronix Type 516 Oscilloscope, the Project Engineer easily checks a welding gate output (lower trace) with respect to the trigger pulses (upper trace) and quickly notes any variations.

Consider the Type 516 Oscilloscope for your own DC-to-15 MC applications. It offers you four operating modes, independent controls for each amplifier channel, bright traces with excellent definition. You can position, attenuate, invert input signals as necessary for your own dual-trace or single-trace research and development projects.

Type 516 performance characteristics include: risetime of 23 nanoseconds, calibrated vertical sensitivity of 50 mv/div to 20 v/div, calibrated sweep range of 0.2 μsec/div to 2 sec/div. Other Tektronix features include: flexible trigger facilities (with high-frequency sync to 20 mc), 5X Magnifier, Amplitude Calibrator, electronically-regulated power supplies.

Type 516 Oscilloscope (50-60 cycles) *f. o. b. factory* . . . **$1000**

For a demonstration of the Type 516 Oscilloscope in your own laboratory, call your Tektronix Field Engineer.

Tektronix, Inc.

P. O. Box 500 • Beaverton, Oregon • Phone Mitchell 4-0161 • TWX—BEAV 311 • Cable: TEKTRONIX

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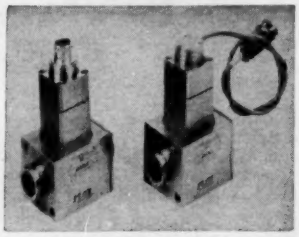
TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics, Portland, Oregon • Seattle, Washington. Tektronix is represented in twenty overseas countries by qualified engineering organizations.

In Europe please write Tektronix Inc., Victoria Ave., St. Sampsons, Guernsey C.I., for the address of the Tektronix Representative in your country.

CIRCLE 138 ON READER-SERVICE CARD

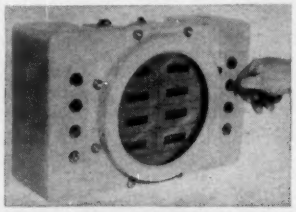
FLOW TRANSDUCERS



New Series SF2 Flow Transducers have ranges of 0 to 0.5 gps through 0 to 200 gpm. Signal conditioning amplifier provides 5-v full scale output for telemetry. Full bridge system with four active bonded strain gage elements sense flow force on cantilever reed in flow stream. Sensitivity 4 mv/v, flow unidirectional, linearity 2% of full scale, repeatibility less than 0.25%.—*Standard Controls, Inc.*, 1130 *Poplar Place, Seattle* 44, *Wash.*

CIRCLE 311 ON READER-SERVICE CARD

BULK MEASUREMENT CONTROL



New automated Measurement Control Systems for loading fluids at bulk storage terminals uses a key to activate the entire electrical control system, consisting of an explosion-proof impulse contactor and explosion-proof key control panel. System can be used with predetermined batch control. Ticket printer serves all keyholders on any one metered system.—*Rockwell Mfg. Co.*, 400 *N. Lexington Ave., Pittsburgh* 8, *Pa.*

CIRCLE 312 ON READER-SERVICE CARD

DIFF PRESS CALIBRATOR

New Portable Differential Pressure Tester and Calibrator is for inspection and reliability assurance of mobile atomic reactors. Permits checking installed equipment from remote position. Characteristics—differential pressure range; 600″ W.C. Accuracy: Basic model ±0.03″ W.C.; with 0.1% dial manometer: ±0.15″ W.C. ±0.63″ W.C. Sensitivity: ±0.27″ W.C. ±0.75″ W.C. Weight: 45 lb (approx).—*American Research & Mfg. Corp.*, 920 *Halpine Ave., Rockville, Md.*

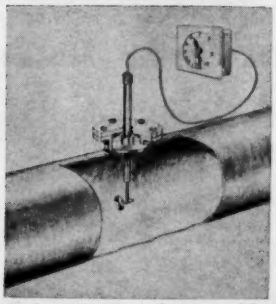
CIRCLE 313 ON READER-SERVICE CARD

SUPERVISORY CONTROL

New Audio Tone Channels for remote supervisory control and telemetry include the AM (ON/OFF Type) and FS (Frequency Shift) Tone Units. A pair of telephone wires, microwave, or radio are used for multiplexing or combining the audio tone channels independently, simultaneously and continuously for remote operations. 10 AM and FS transmitter and receiver modules, plus a power supply can be combined in a 5¼" and 19" frame or rack.—*Quindar Electronics, Inc., 5 Lawrence St., Building 9, Bloomfield, N. J.*

CIRCLE 314 ON READER-SERVICE CARD

FLOW TRANSDUCER



New improved probe-type Mark V Flow Transducer measures fluid flows to 5000 psi and 600°F in large pipe lines, is installed through flanged fitting fabricated in pipe lines. Uses strain gages to sense rate of fluid flow as product of dynamic forces acting upon fixed body immersed in flow stream; can be remotely located. —*Ramapo Instrument Co., Inc., 8 First St., Bloomingdale, N. J.*

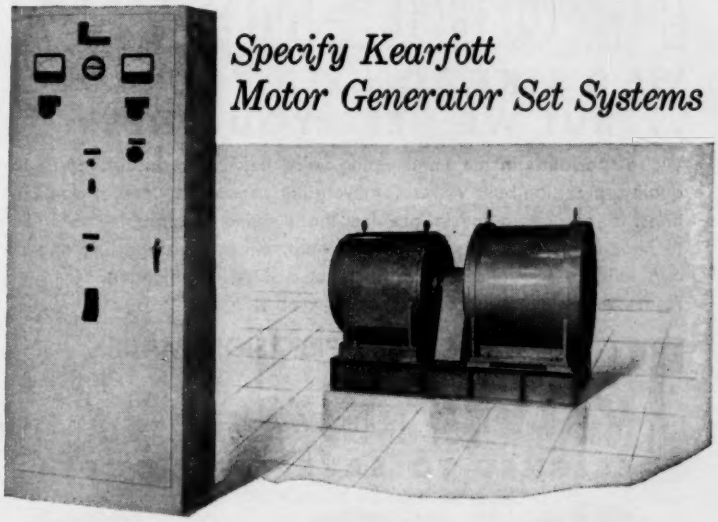
CIRCLE 315 ON READER-SERVICE CARD

LIGHT INDICATOR MODULES

New Weld-Pac Light Indicator Modules need only external power supplies and trigger signals. Four modules (WM-2000 to 3) employ transistor amplifiers and glow lamps; two (WM-2004, 5) use transistors and incandescent lamps. WM-2006 uses filamentary thyratrons, is four times brighter; WM-2007 employs cold cathode thyratron, is seven times brighter than other modules.—*Industrial Components Div., Raytheon Co., 55 Chapel St., Newton 58, Mass.*

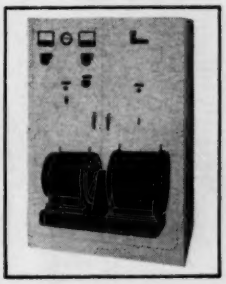
CIRCLE 316 ON READER-SERVICE CARD

FOR PRECISE 400-CYCLE POWER



Specify Kearfott Motor Generator Set Systems

Kearfott 60-to-400 cycle motor generator frequency converters are in active use wherever precise 400-cycle power must be supplied . . . including laboratories and in such other representative applications as production testing, high speed tool operation and ground support. These generator systems, which consist of a 60 cycle synchronous motor and a 400 cycle generator, can be supplied with controls and generator as an integral, compact unit—or with controls and generator separately located.



PERFORMANCE SPECIFICATIONS

Frequency: 400 cycles under any rated load condition with 60 cycle input.

Voltage Regulation: Within ±1% of rated voltage when (1) load varies between no-load and 125% of rated load, and/or (2) load power factor varies between 0.8 lagging and unity, and/or (3) equipment temperature varies after approximately 10 minutes' operation.

Voltage Recovery: When rated load is suddenly applied or removed, voltage will return to and remain within regulating band within 0.25 seconds.

Voltage Adjustment: Continuously adjustable to ±10% of rated value.

Deviation Factor: Maximum 4% between no load and full load.

Overload: Equipment delivers 125% of rated load for 2 hours.

Amplitude Modulation: Maximum 1% of peak-to-peak voltage at any load between no load and full load, at any power factor between 0.8 lagging and unity.

Frequency Modulation: Maximum 0.5% at any load from no load to 125% of rated load.

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE 139 ON READER-SERVICE CARD

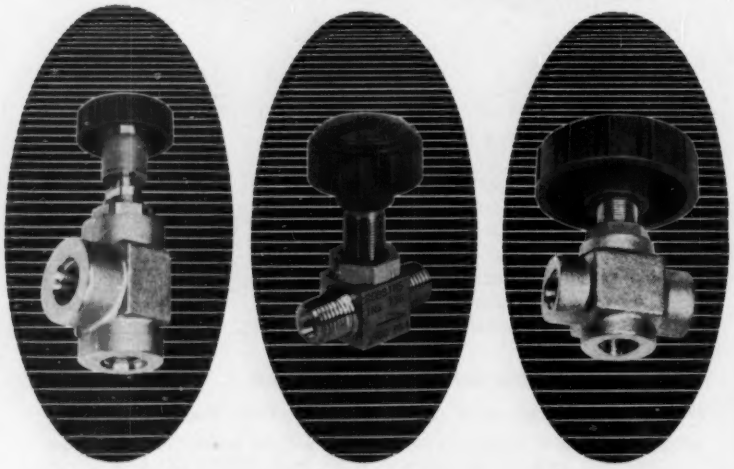
DO YOU HAVE PROBLEMS IN THE SMALL PIPING FIELD?

WE'D LIKE TO HELP YOU ...BUT WE NEED YOUR HELP

We're specialists in the small piping valve field...producing very high quality, precision-built valves for everyday as well as unusual applications. If you have a special problem that's giving you trouble, we'd like to hear from you...possibly we can help, either by suggesting one of our standard specialized valve items, or a slight modification. Please write, giving us complete details. DO IT TODAY!

ROBBINS VALVES ARE PRECISION MADE FOR PERFORMANCE!

DESIGNED TO SAVE YOU MONEY!



HIGH PRESSURE | INSTRUMENT | THREE-PORT

Here are three typically unique items in the Robbins Valve line. The high pressure valve operates up to 12,000 PSI, is pressure balanced, easily operated, panel mounts in one minute, serviced from front of panel. The instrument valve is really miniature... weighs only 0.31 lb., body is only ¾" square, operates from hi-vacuum to 3500 PSI, provides absolute shut-off, low torque, fine metering control, leakproof operation. The three-port valve simplifies stocking problems...can be used as globe or angle valve (with sealing plug), or with relief valve, pressure gauge or another line connection in third port.

Write TODAY for 16-page illustrated brochure in color! AND...if you have a special problem in valving of small piping...include all details. We'd like to help.

ROBBINS Aviation Inc.

3817 S. Santa Fe Ave.
Los Angeles 58, California
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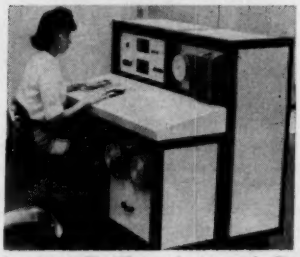
CIRCLE 140 ON READER-SERVICE CARD

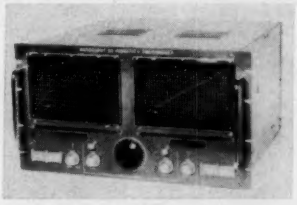
TAPE PREPARATION



New TAPE (Tape Automatic Preparation Equipment) is said to produce perfect punched tape at "less than half the cost and in less than one-third of the time required by the best standard computer preparation methods now available." Logic circuitry analyzes word-group and keyboard commands and converts them to complete coded programs. Edits, verifies, duplicates, and corrects the punched tape automatically.—*McDonnell Aircraft Corp., St. Louis* 66, *Mo.*

CIRCLE 317 ON READER-SERVICE CARD

DUAL CHANNEL PROGRAMMER



New Marquardt dual channel Automatic Programmer employs automatic controls and two Perkin-Elmer Vernistat function generators, each with 34 manual set sliders to permit operator to "draw" desired program on each function generator. Programmer continuously controls any two independent variables vs time.—*Marquardt Corp.*, 16555 *Saticoy St., Van Nuys, Calif.*

CIRCLE 318 ON READER-SERVICE CARD

VOLTAGE-TO-FREQUENCY CONVERTER

New fully transistorized Model 1011 for measuring dc voltage to 0.1% accuracy with any standard frequency counter, develops an output frequency precisely proportional to the input voltage. Input (floating) voltage ranges: 0 to 1, 0 to 10, 0 to 100, and 0 to 1000 v dc. Output frequency: 10,000 cps to 11,000 cps Linearity: 0.1% f.s.d.—*Lome Electronics, Inc.*, 8526 *N. New Braunfels, San Antonio* 9, *Tex.*

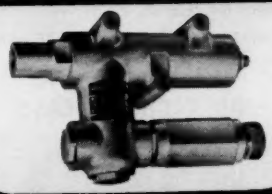
CIRCLE 319 ON READER-SERVICE CARD

Specify

Amot controls

They Give Your Engines Maximum Protection!

AMOT Model 4023 High Pressure Valve has balanced 3-way action. Suitable for pressures from 250 to 6000 psi.



AMOT Model 4021 Temperature Valve has a balanced 3-way action for pilot pressure control in any control system. Actuating temperature settings from 95 to 235° F. Available also with extensions.

AMOT Model B Thermostatic Valve has become Industry's STANDARD for Engine, Compressor, and Process temperature control. It is tamper proof. Available in 1½" to 6" in cast iron, ductile iron or bronze.

Amot controls
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THERMOSTATS
CONTROLS
SWITCHES VALVES
SAFETY CONTROLS

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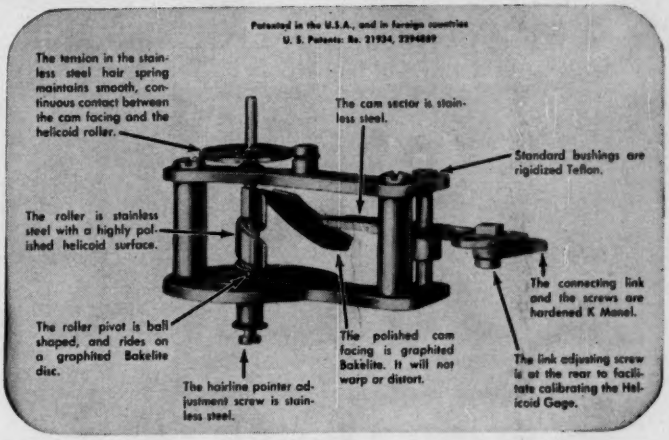
ACCO Helicoid Gage U.S.A.


Patented in the U.S.A., and in foreign countries
U. S. Patents: Re. 21934, 2294889
The tension in the stainless steel hair spring maintains smooth, continuous contact between the cam facing and the helicoid roller.
The cam sector is stainless steel.
Standard bushings are rigidized Teflon.
The roller is stainless steel with a highly polished helicoid surface.
The connecting link and the screws are hardened K Monel.
The roller pivot is ball shaped, and rides on a graphited Bakelite disc.
The polished cam facing is graphited Bakelite. It will not warp or distort.
The link adjusting screw is at the rear to facilitate calibrating the Helicoid Gage.
The hairline pointer adjustment screw is stainless steel.

Exclusive Helicoid movement provides... *Sustained Accuracy... on the toughest jobs*

• Helicoid Gages have no gears, no teeth, reducing wear to an absolute minimum. No danger of fouling, either—rolling action of cam facing keeps contact surface clean. Helicoid Gages have been tested through 75,000,000 cycles, with virtually no wear or loss of accuracy, while conventional geared gages became useless after 500,000 cycles.

Helicoid Gages give *sustained* accuracy even when subjected to violent pressure pulsations or mechanical vibrations. Pointer can be set externally, without removing glass, and cannot be jarred out of position. Dial faces are easy to read, won't corrode or chip. A full range of Helicoid Gages is available for any application. Next time, specify Helicoid—the gage that *stays* accurate.

Bourdon Tubes won't Stretch, Leak, or Crack

Helicoid Bourdon tubes are made from seamless tubing, and are designed for maximum torque and minimum stress. At the factory, each tube is individually tested, overpressured, and stress relieved. Four materials—alloy steel, K Monel, stainless steel, and phosphor bronze—are available to meet applications ranging from tap water to almost any acid.

NEW! Solid-Front Safety Case Gives Added Protection

The new Helicoid solid-front case diverts the force of a burst in a backward direction, away from the operator. The force escapes by deforming, though not detaching, the back cover plate. Helicoid Gages are also available in phenol, acaloy flanged, acaloy flangeless, polished flangeless, round flush, polished flush ring, and square flush cases.

WRITE for details **Ask for Catalog DH-65**

HELICOID GAGES

ACCO

Helicoid Gage Division • American Chain & Cable Company, Inc.

929-B Connecticut Ave., Bridgeport 2, Conn.

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BLH DEVELOPS WORLD'S SMALLEST FULLY INSULATED TEMPERATURE SENSOR ...HT MICRO-MINIATURE THERMOCOUPLE

Response time is reduced significantly by these new fully insulated, electrically fused wire element thermocouples. A typical time constant is 1.2 milliseconds with an exposed junction design immersed in stagnant oil.

Unique construction permits the entire probe and leads to withstand temperatures of the hot junction, which may be (1) exposed, (2) sealed and insulated, or (3) grounded and flattened. All configurations are designed for minimum disturbance of environment.

⅓ the size of a human hair...the sensing element wires are insulated with pure fused ceramic that does not pick up moisture from the air and has a voltage breakdown of 10,000 volts at room temperature. The probe is .014 in. dia., and the lead wires are .010 in. dia. for easy handling.

Cryogenic to 3000°F temperature range makes the HT Micro-Miniature Thermocouple ideal for measuring temperatures of rocket fuels, missile and aircraft skins, jet engine exhausts, atomic piles, and various testing and process operations throughout industry.

Nationally available through 16 BLH sales engineering representatives throughout the U.S. and Canada, these temperature sensors are manufactured by BLH under exclusive license of High Temperature Instruments Corp.

Write us...or contact your nearest BLH representative for a copy of our 6-page product data folder.

BALDWIN • LIMA • HAMILTON
Electronics & Instrumentation Division
Waltham 54, Mass.

FIRST in force measurement

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CIRCLE 143 ON READER-SERVICE CARD

PRESSURE TRANSDUCER

New "Zero-length/dimensionless" unbonded-strain-gage Pressure Transducer, Model P707TC, for absolute and gage pressures from 0-5 psig through 0-5000 psig, features small size, light weight, low sensitivity to acceleration, and excellent thermal performance. Excitation of the P707TC is 5 v (for gage model) and 7 v (for absolute model), dc or ac (rms) through carrier frequencies. Output of the gage model is 25 mv of the absolute model 35 mv. Combined error due to non-linearity and hysteresis is less than ±0.75% of full-scale output.—*Statham Instruments, Inc.*, 12401 *W. Olympic Blvd., Los Angeles* 64, *Calif.*

CIRCLE 322 ON READER-SERVICE CARD

DC TACHOMETERS

New Models R9608-001 and R9608-002 DC Tachometers feature high accuracy, reliability, and long life. Model R9608-001 is an uncompensated unit with output of 7 v/1000 rpm, rated speed of 3600 rpm, and linearity of 0.07% to 3600 rpm. Model R9608-002 is temperature compensated with output of 2 v/100 rpm, rated speed of 5000 rpm, and linearity of 0.1% to 3600 rpm.—*Kearfott Div., General Precision, Inc.*, 1150 *McBridge Ave., Little Falls, N. J.*

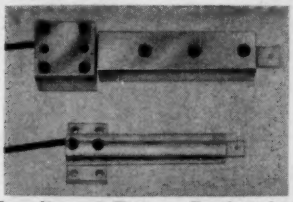
CIRCLE 320 ON READER-SERVICE CARD

RESISTANCE BRIDGES

New high-accuracy Synchro and Resolver Resistance Bridge consist mainly of a balanced, non-inductive resistance network—a delta arrangement for the synchro bridge and a four sided arrangement for the resolver bridge. Each bridge can be indexed to any multiple of 5° throughout a range of 0° to 360°.—*Kearfott Div., General Precision, Inc.*, 1150 *McBridge Ave., Little Falls, N. J.*

CIRCLE 321 ON READER-SERVICE CARD

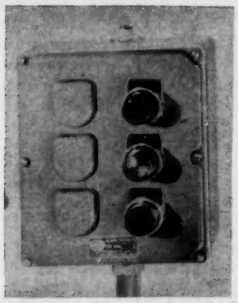
SEMICONDUCTOR LOAD CELLS



New line of Bytrex Semiconductor Load Cells utilizes semiconductor strain-sensitive elements in the form of a Wheatstone bridge whose resistance change is proportional to applied load or deflection. Ranges: from ±½ to ±100 lb. Spec Sheet SP-1002. —*Kulite-Bytrex Corp., 50 Hunt St., Newton 58, Mass.*

CIRCLE 323 ON READER-SERVICE CARD

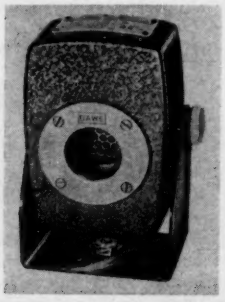
LIQUID LEVEL ALARMS



New line of Liquid Level Alarms can be used with any liquid in any rented storage or processing vessel. Alarms turn on a built-in signal light and sound an external horn or bell when the liquid reaches the pre-determined level. Available for response at high level, low level, and both high and low level. Bulletin EX-700.—*King Engineering Corp., Box 740, Ann Arbor, Mich.*

CIRCLE 324 ON READER-SERVICE CARD

ACOUSTIC CALIBRATOR



New Type 1417 portable Acoustic Calibrator (Made in England) for the periodic calibration of sound level meters operates on a solely mechanical system of falling balls which produce a noise repeatable within ±1 db. Produced noise level is as high as 90 db at 4" from microphone.—*Korfund Co., Inc., 78W Cantiague Rd., Westbury, N. Y.*

CIRCLE 325 ON READER-SERVICE CARD

Moeller Exclusives Provide Timeless Accuracy

Moeller Mercury-Actuated-Dial-Indicating Thermometers are designed and constructed to provide dependable accuracy with minimum maintenance. They are available both in direct reading and remote types.

Gasketed phenolic cases are furnished in 4½", 6" and 8" sizes for flush or surface panel mounting. Brass cases can be furnished on special order.

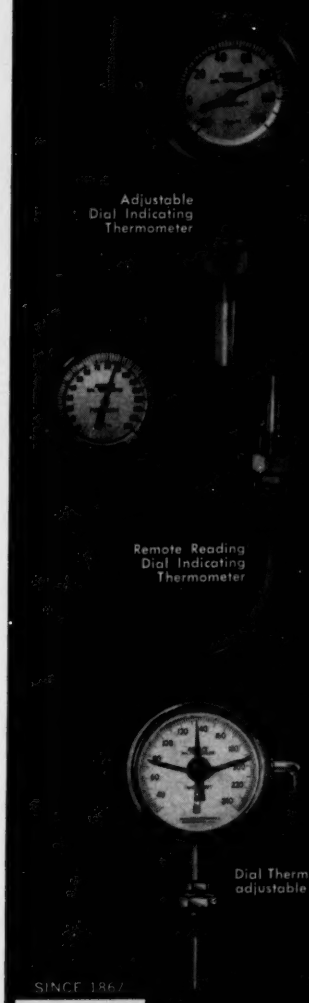
Standard ranges are supplied between —40° F. and +1200° F. Special ranges and combination scales can be made to order. The bourdon spring, which is the heart of the instrument, is specially designed and heat treated for long life and accuracy.

Moeller Micro accurate stainless steel capillary tubing has a smooth internal diameter, held to close tolerance. Standard armor is spirally wound stainless steel. Other armors such as smooth lead, polyvinyl chloride, etc., are also available. Tubing lengths can be furnished up to 150 ft. Lengths over 50 ft. may be ordered with full compensation. Anti-parallax scales are standard.

All dials are compensated for temperature variations around the case. Units are available with plain bulbs, union connection bulbs and separable sockets. Separable sockets also can be fabricated from all commercial metals with thread, flanged and Van Stone connections.

Dial thermometers can be furnished with high and low alarm contacts.

Moeller has a dial thermometer to meet your specific needs. See your Moeller Representative or write today for Catalog No. 150.



Adjustable Dial Indicating Thermometer

Remote Reading Dial Indicating Thermometer

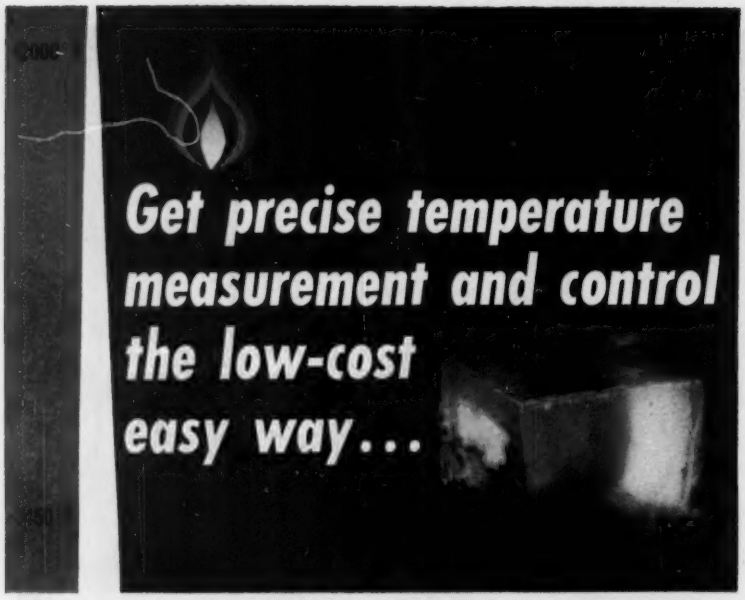
Dial Thermometer with two adjustable electrical contacts

SINCE 1867

MOELLER INSTRUMENT COMPANY, Inc.
132nd Street and 89th Avenue, Richmond Hill 18, N.Y.

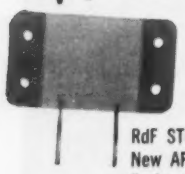
Representatives in principal cities.

CIRCLE 144 ON READER-SERVICE CARD



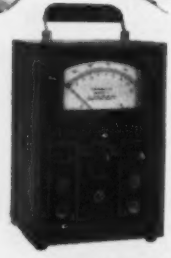
...insist on RdF STIKONS & STRAPONS

RdF STIKON BN Series


RdF STIKON New APM Series

RdF STRAPON RN-100

RdF STRAPON RNM-100-1


RdF INDICATORS

RdF STIKON® resistance thermometers for surface temperature measurement were pioneered by RdF Corporation (formerly Arthur C. Ruge Associates, Inc.). These versatile transducers are characterized by millisecond response, high sensitivity, accuracy, stability and high output. Recent developments in adhesives now make it possible to bond RdF STIKONS easily and quickly to virtually any surface. Available in a wide variety of grid styles and carrier materials. Latest addition to the line is the APM Series with temperature ratings of —450° to 2000°F.

RdF STRAPON resistance thermometers, a modification of the RdF STIKON, are mounted on a stainless steel shim overmolded with silicone rubber. These rugged, re-usable sensors can be strapped to the outside of a pipe to measure the temperature of fluid inside without shutting down a process, interrupting flow or cutting holes in pipes. RdF STRAPONS are designed to operate at continuous temperatures from —100° to 500°F.

RdF PROBES—To supplement the established capability of RdF resistance thermometers for surface measurements, RdF Corp. offers a complete line of standard, mounted and miniature probes for measuring temperature in any situation.

RdF PORTABLE INDICATORS—A series of low-cost, direct-reading temperature indicating instruments for use with RdF resistance thermometers. Easy to use, accurate, dependable. Battery or AC power supply optional.

If you have a temperature measurement/control problem, contact us for the name of your nearest RdF sales engineer. Write today for RdF STIKON Catalog and Price List #T-59 and for RdF Products Bulletin #T-60A.

RdF Corporation
Hudson, New Hampshire

Nashua, N.H., TUxedo 2-5195 TWX NASH 188-U

CIRCLE 145 ON READER-SERVICE CARD

DRUM-PROGRAMMED TESTER

New D-PAT (for drum-programmed automatic tester) using a digital computer with test program procedures stored on a magnetic memory drum whirring at 2,300 rpm, detects and isolates malfunctions in any system. Then, from its library of 35-mm slides, it flashes repair instructions on a 15" view screen, displaying a picture of the malfunctioning circuit or assembly with a bright red arrow spotted over the component that is causing the trouble and needs replacing. D-PAT also predicts the remaining useful life of a component by comparing its operation with its past performance and with the manufacturer's specifications.—*Hughes Aircraft Co., Florence Ave. & Teale St., Culver City, Calif.*

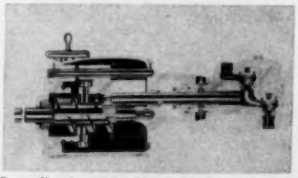
CIRCLE 326 ON READER-SERVICE CARD

VAPOR TENSION THERMOMETER

New Series 8000 vapor-tension-actuated Equipment Thermometers are remote indicators for refrigerators, ovens, engines, etc. Units have Bourdon-tube internals, 2", 2½" and 3½" dials, 10 standard ranges.—*U. S. Gauge Div., American Machine & Metals, Inc., Sellersville, Pa.*

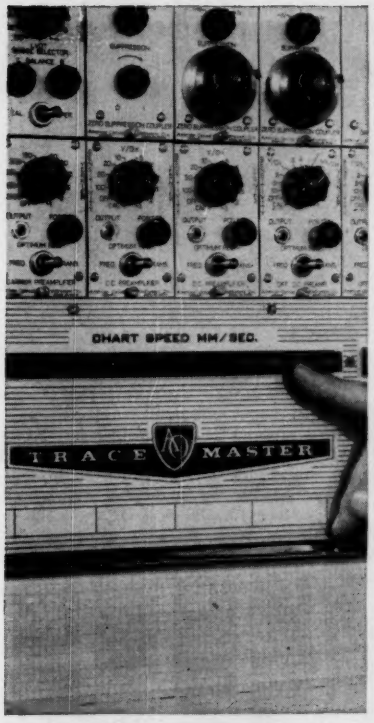
CIRCLE 327 ON READER-SERVICE CARD

PROPORTIONING PUMP



New Series 300 Proportioning Pump can be adjusted while pump is running. Features include new control mechanism, interchangeable liquid ends, all moving parts enclosed in a compact housing for use in high corrosion environments. Capacities range from 1-812 gph (for the simplex model) to 2-1624 gph (for the duplex model). Maximum working pressure is 10,000 psig.—*American Meter Pump Div.*, 13500 *Philmont Ave., Phila.* 16, *Pa.*

CIRCLE 328 ON READER-SERVICE CARD



5000:1 CHART SPEED CHANGE RATIO WITH AO TRACEMASTER

The AO Tracemaster 8-channel Direct Writing Recorder provides 5000:1 chart speed change ratio... 2½ times greater than any other recorder. A simple push-button control panel provides 10 chart speeds from 0.1 mm/sec. to 500 mm/sec.

Chart drive response is virtually instantaneous. You can go from a dead stop to full 500 mm/sec. in less than 1/10 of a second... there's no need for adapters or gear shifting... no loss of record and no slack while chart speed stabilizes.

1000 ft. chart roll lets you do high chart speed recording at length with fewer interruptions for reloading. Accurate, easy-to-read "Remaining Footage" indicator prevents accidental loss of record due to unexpected chart shortage.

This unequalled chart speed change ratio of 5000:1 is just one more example of the overall superiority of the remarkable AO Tracemaster... the world's newest and finest 8-channel direct writing recorder.

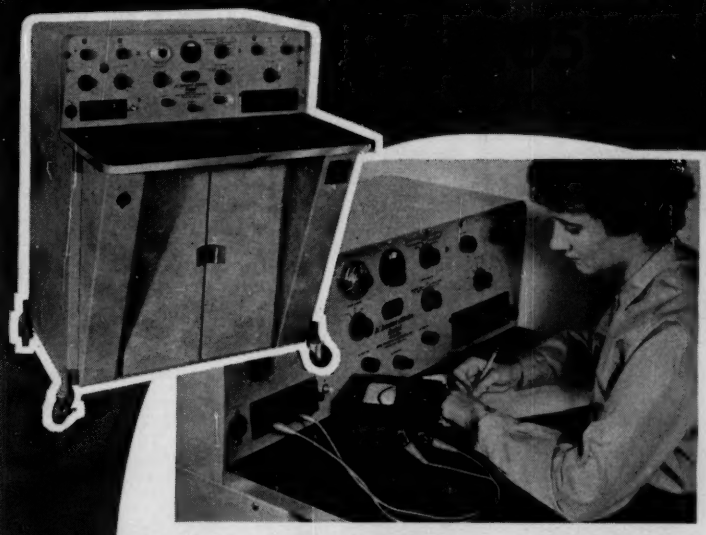
Write for complete information... Now! 32-page, 2-color catalog is yours for the asking.

American Optical Company

Instrument Division • Buffalo 15, New York

CIRCLE 146 ON READER-SERVICE CARD

AC Instrument Calibration



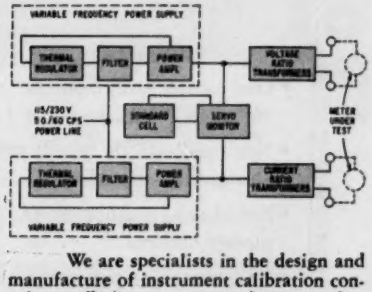
Voltmeters and ammeters, plus wattmeters, are quickly calibrated over frequencies from 50 to 2400 cps by one operator.

The Model 1967 Semi-Automatic AC Instrument Calibration Standard provides, in a single convenient console, a precise and rapid means for standardizing and calibrating alternating current wattmeters, expanded scale, digital, indicating and recording voltmeters and ammeters.

Basic accuracy is maintained by an AC reference source consisting of a servo amplifier, thermal transfer circuit and a sensitive light beam galvanometer all balanced against a ±.01% laboratory type standard cell. Resistive components are made of selected manganin properly heat-treated, aged for six months and adjusted to ±.01% of absolute value. The thermoelement is unaffected by waveform errors, has flat frequency response and is protected against overloads.

MODEL 1967 CALIBRATION RANGES

AC VOLTAGE		AC CURRENT	
RANGE	MIN. LOAD RESISTANCE	RANGE	MAX. LOAD RESISTANCE
0-1.5 MV	20,000 ohms	0-15 μA	10,000 ohms
0-3.0 MV	20,000 ohms	0-30 μA	10,000 ohms
0-7.5 MV	20,000 ohms	0-75 μA	10,000 ohms
0-15 MV	20,000 ohms	0-150 μA	10,000 ohms
0-30 MV	20,000 ohms	0-300 μA	10,000 ohms
0-75 MV	20,000 ohms	0-750 μA	10,000 ohms
0-150 MV	20,000 ohms	0-1.5 MA	1,000 ohms
0-300 MV	20,000 ohms	0-3.0 MA	1,000 ohms
0-750 MV	20,000 ohms	0-7.5 MA	1,000 ohms
0-1500 MV	1,000 ohms	0-15 MA	1,000 ohms
RANGE	MAXIMUM LOAD	RANGE	MAXIMUM LOAD
0-1.5 Volts	2 VA	0-0.15 Amp	10 VA
0-3.0 Volts	3 VA	0-0.3 Amp	10 VA
0-7.5 Volts	5 VA	0-0.75 Amp	10 VA
0-15 Volts	10 VA	0-1.5 Amp	10 VA
0-30 Volts	15 VA	0-3.0 Amp	10 VA
0-75 Volts	15 VA	0-7.5 Amp	10 VA
0-150 Volts	15 VA	0-15 Amp	10 VA
0-300 Volts	15 VA	0-30 Amp	10 VA
0-750 Volts	15 VA	0-75 Amp	10 VA
0-1500 Volts	15 VA		



We are specialists in the design and manufacture of instrument calibration consoles — offering more types than any other source in the world. Accuracy of all units is certificated and traceable to primary standards maintained by the National Bureau of Standards.

Performance is rigidly guaranteed. Prices are f.o.b. Boonton, N.J. and subject to change without notice.

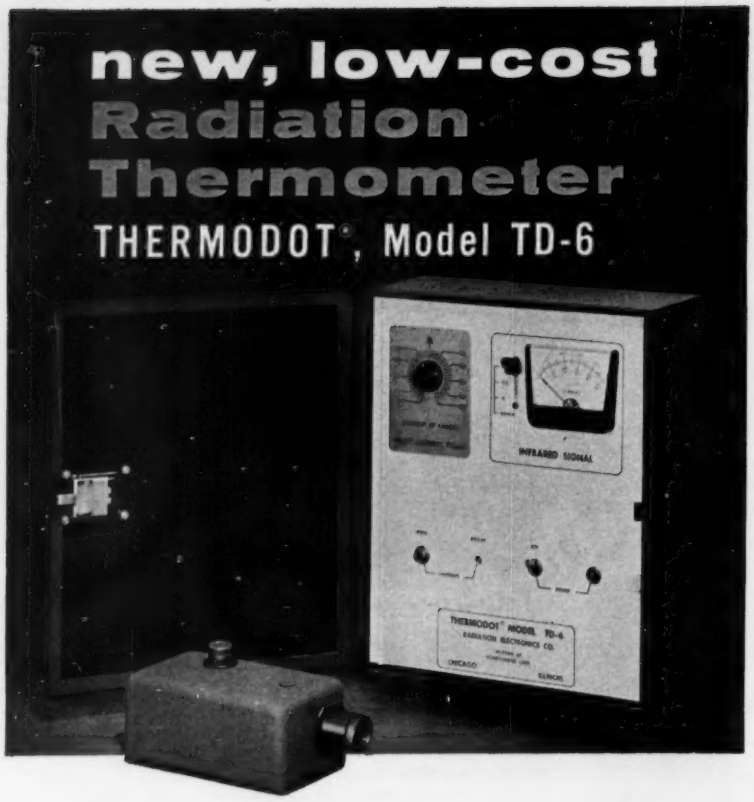
SEND FOR TECH. DATA

For additional information, including application data, write or phone DE 4-3100. Demonstrations available by local representatives.

Radio Frequency LABORATORIES, INC.

Boonton, New Jersey, U.S.A.

CIRCLE 147 ON READER-SERVICE CARD



Measures and controls temperature without contact

- Engineered for plant use: production, testing, quality control
- Lens focuses easily from 20″ to infinity, "sees" isolated spot size ⅛″ at 20 inches, 1 inch at 12 ft., etc.
- Non-parallax sight exactly defines spot size and identifies work area to be measured
- Broad temperature range: 210°F to 3300°F (higher range models optional)
- Pushbutton temperature calibration at control panel
- Ambient temperature compensation; emissivity adjustment from 0.1 to 1.0
- Sensitivity: 0.2% of temperature, e.g., 1°F at 500°F
- Response time: 0.3 second to 95% of full scale
- 0-10 mv. output for recorders, indicators, controllers (standard); internal relay control (optional)
- BASE PRICE . . . $775.00

For more information, write for Bulletin R-103.

Dept. C-5

RADIATION ELECTRONICS CO.
DIVISION OF COMPTOMETER CORPORATION
5600 Jarvis Avenue • Chicago 48, Illinois • Telephone SPring 5-2400

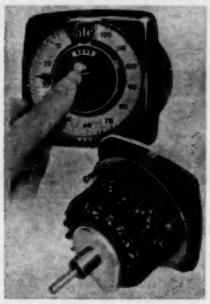
CIRCLE 148 ON READER-SERVICE CARD

TELEMETRY DISCRIMINATOR

New solid-state single-channel Telemetry Discriminator, Type 42-7952, has frequency deviation, standard ±7.5% or ±15% IRIG; straight line deviation ±0.25% or better of bandwidth; response within 0.5 db throughout standard IRIG intelligence bandwidth. Size allows 18 units to mount on relay rack panel only 8¾″ high.—*Airpax Electronics Inc., Seminole Div., Fort Lauderdale, Fla.*

CIRCLE 329 ON READER-SERVICE CARD

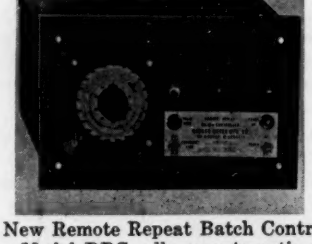
REVOLUTION COUNTER



New Series 312 Atcotrol shaft-driven Revolution Counter has integral push-button, couples to rotating shaft at constant or variable speed up to 2000 rpm with repeat count accuracy ¼ of 1% of dial range. Controls process, batch system, or automatic flow. In 11 standard dial ranges from 0-12 to 0-6000 revolutions (special ranges available).—*Automatic Timing & Controls, Inc., King of Prussia, Pa.*

CIRCLE 330 ON READER-SERVICE CARD

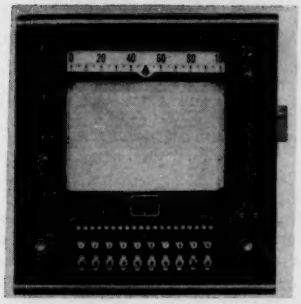
REMOTE BATCH CONTROLLER



New Remote Repeat Batch Controller, Model RBC, allows automatic remote control of measuring, mixing, blending, or batching of fluids. Unit has reset totalizer, counter to set batch quantity up to 1,000 gal, push-button start switch, and stop switch. Bulletin RBC.—*Badger Meter Mfg. Co., Industrial Products Div., 4545 W. Brown Deer Rd., Milwaukee, Wis.*

CIRCLE 331 ON READER-SERVICE CARD

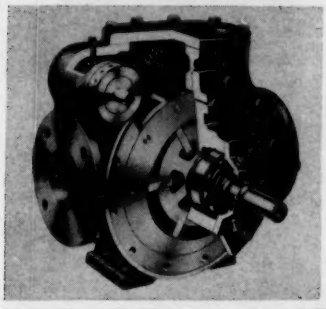
ALARM SCANNER



New transistorized Alarm Scanner scans up to 200 measured variables at 1 pt./sec. "Off-Normal" activates recorder, actuates red lamp and alarm system.—*Bristol Co., Waterbury 20, Conn.*

CIRCLE 332 ON READER-SERVICE CARD

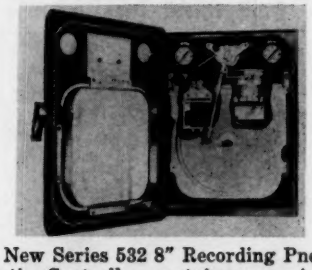
PROPORTIONING PUMP



New Vari-Flo Pump is essentially a vane-type positive-displacement pump with addition of a unique flow-changing device that varies the pump capacity from zero to full flow by means of a calibrated dial. Used in line blending of asphalts, various grades of gasoline (to obtain intermediate octane ratings), or the blending of heavy and light grades of lube oils or fuel oils, etc.—*Blackmer Pump Co., 1809 Century Ave., Grand Rapids, Mich.*

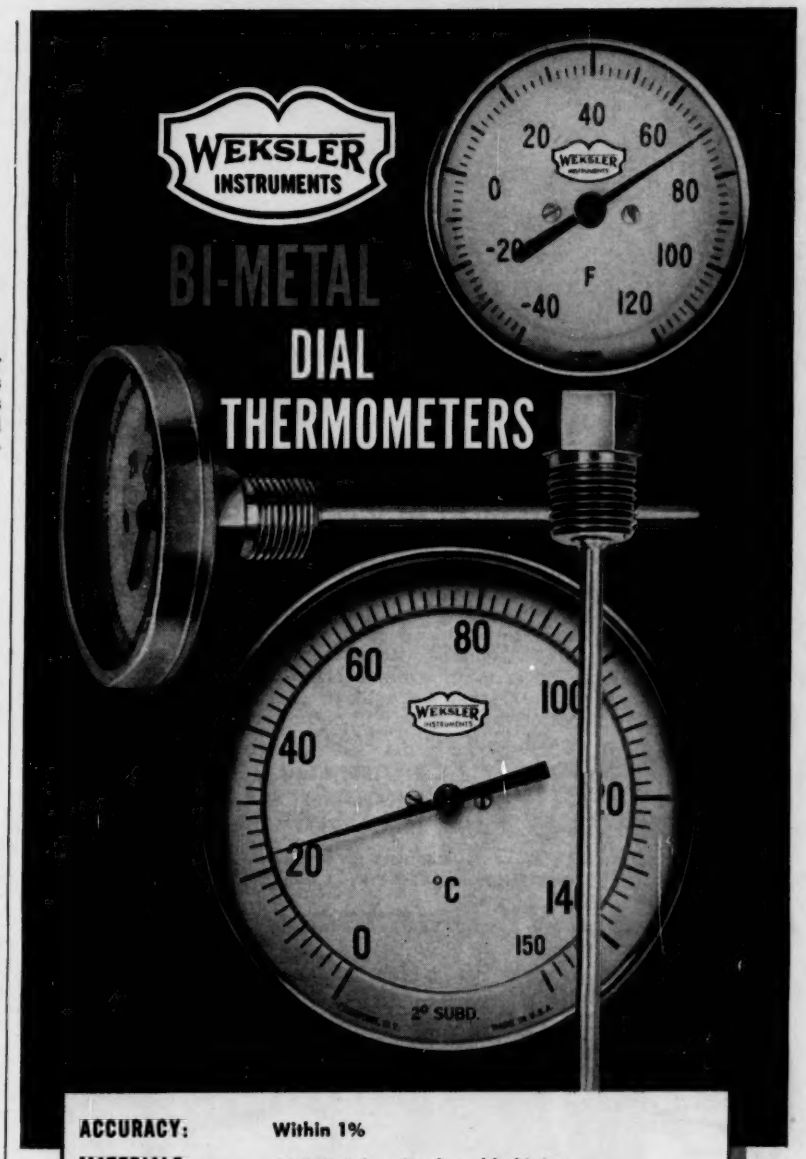
CIRCLE 333 ON READER-SERVICE CARD

RECORDING CONTROLLER



New Series 532 8" Recording Pneumatic Controller contains new A/D control unit and features good frequency response (essentially flat to over 300 cpm), low air consumption (less than 0.1 scfm), high exhausting capacity (well over 3 scfm at 1 psi drop). Available with a choice of four modes of control for pressure, temperature, flow, humidity, or differential liquid level.—*Bristol Co., Waterbury 20, Conn.*

CIRCLE 334 ON READER-SERVICE CARD



ACCURACY:	Within 1%
MATERIALS:	18-8 Stainless Steel, *welded* joints
WORKMANSHIP:	The finest, right through to *individual calibration*
COST:	Being Weksler, cost is *always* moderate

Weksler Bi-Metal Dial Thermometers are incomparable for every type of scientific temperature measurement. Dished anti-parallax dials, stem lengths to fit *all* standard thermo-wells, gasket sealed bezels, heavy crystal, *external* adjustment, and *all* standard F and C ranges are features you expect and *get* from Weksler!

WRITE FOR BULLETIN 700

WEKSLER INSTRUMENTS

"ORIGINATORS OF WORLD RENOWNED ADJUST-ANGLE THERMOMETERS"

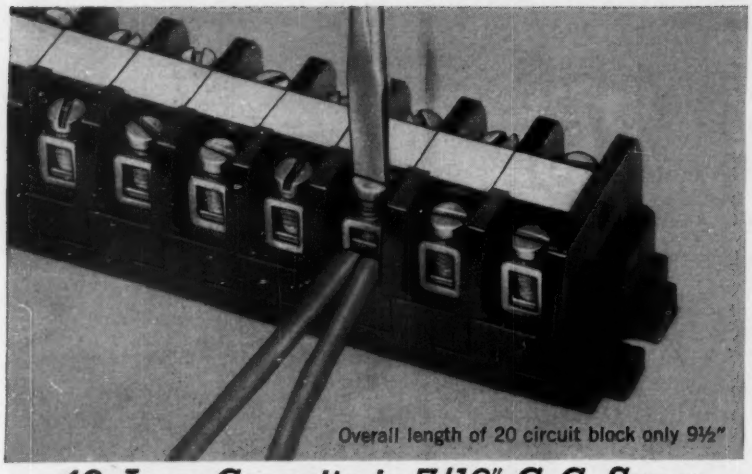
WEKSLER INSTRUMENTS

CORPORATION

195 EAST MERRICK ROAD, FREEPORT, L. I., N. Y.

Indicating and Recording Instruments for Temperature, Pressure and Humidity

CIRCLE 149 ON READER-SERVICE CARD



40 Amp. Capacity in 7/16" C. C. Space Same As Most 15 Amp. Barrier Strips

Buchanan has this . . . and more. No terminals, no lugs, fewer wiring problems when you use Buchanan sectional MD pres-SURE-blocks with tubular contacts. And, you can group more common wires—equal to 1 #22 thru 1 #8—under a single contact. Just 2 different snap-fit parts build any length Buchanan MD block . . . with more "wanted" features than conventional blocks. Strap screw contacts also available. Write now for Bulletin IC-5

Tubular contacts listed by UL. Blocks listed for 600 volts by CSA. U. S. Pat. No. 2,922,139

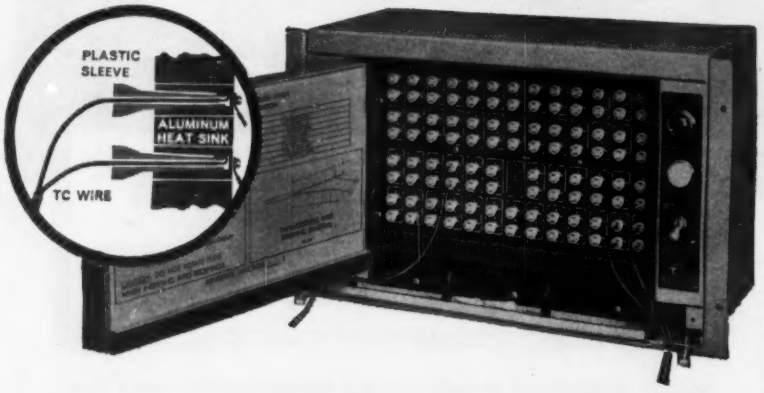
BUCHANAN ESNA

BUCHANAN ELECTRICAL PRODUCTS CORPORATION
HILLSIDE, NEW JERSEY
In Canada: ESNA CANADA LIMITED, Toronto 16

BOOTH 720 & 726 DESIGN ENGINEERING SHOW MAY 22-25.

CIRCLE 150 ON READER-SERVICE CARD

Now, use ANY thermocouple!



New R-I UNIVERSAL HOTBOX

provides reference junctions for all types of thermocouples interchangeably, eliminates need for special compensators or wire-matching plugs.

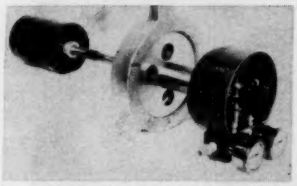
Applications: Data Handling Systems
Exotic Thermocouples

R-I RESEARCH INCORPORATED

Write Dept. IC, Box 6164, Minneapolis 24, Minn.

CIRCLE 151 ON READER-SERVICE CARD

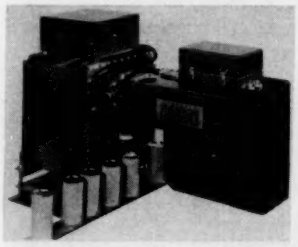
LIQUID LEVEL CONTROL



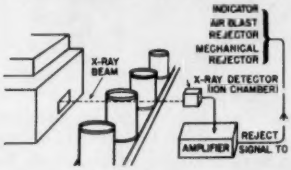
New High Pressure Float Control, Model CTU-415S, features a positive-displacement-type float, proportional pneumatic output, and pressures up to 1500 psig. Bulletin P-261.—*Instruments, Inc., Box 556, Tulsa, Okla.*

CIRCLE 335 ON READER-SERVICE CARD

CONTAINER INSPECTOR



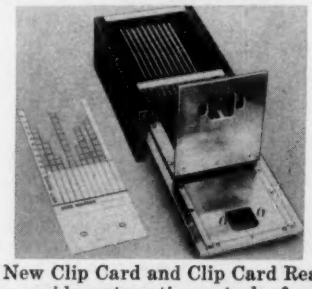
BASIC PRINCIPLE OF HYTAFILL 1000 OPERATION



New X-ray Inspector, Hytafill 1000, for fill-height inspection speeds of 1000 containers/min includes new ion chamber radiation detection system. Monitors fill height of any sufficiently dense liquid or free-flowing solid. Accuracy within ±1/64", or 2½ grams in 12-oz container.—*General Electric Co., X-Ray Dept., 4855 W. Electric Ave., Milwaukee, Wis.*

CIRCLE 336 ON READER-SERVICE CARD

CLIP CARD READER



New Clip Card and Clip Card Reader provide automatic control of program, formula, position, etc., at low cost. Direct reading eliminates need for relays or stepping switches. Reader and cards are capable of more than 1,000,000 readings with repeat accuracies of better than one part in 1,000.—*Jordan Controls, Inc., 3235 W. Hampton Ave., Milwaukee 9, Wis.*

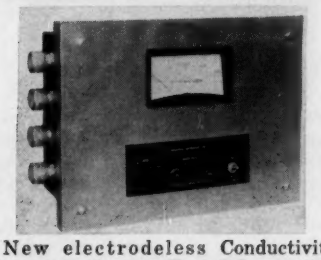
CIRCLE 337 ON READER-SERVICE CARD

DIGITAL READOUT

New Series 160 in-line Digital Display Readout displays 1½" high digits and makes more complete use of total screen surface area. Twelve miniature lamps and condensing lenses carry and project the desired message.—*Industrial Electronics Engineers, Inc.*, 5528 *Vineland Ave., North Hollywood, Calif.*

CIRCLE 338 ON READER-SERVICE CARD

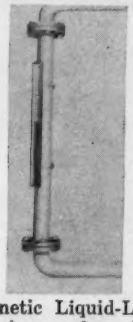
CONDUCTIVITY MEASUREMENT



New electrodeless Conductivity Measuring System, Type RS, provides a stable 0-10 mv d-c output for operating a standard potentiometer recorder or recorder-controller. Particularly applicable for difficult environments.—*Industrial Instruments, Inc.*, 89 *Commerce Rd., Cedar Grove, Essex County, N. J.*

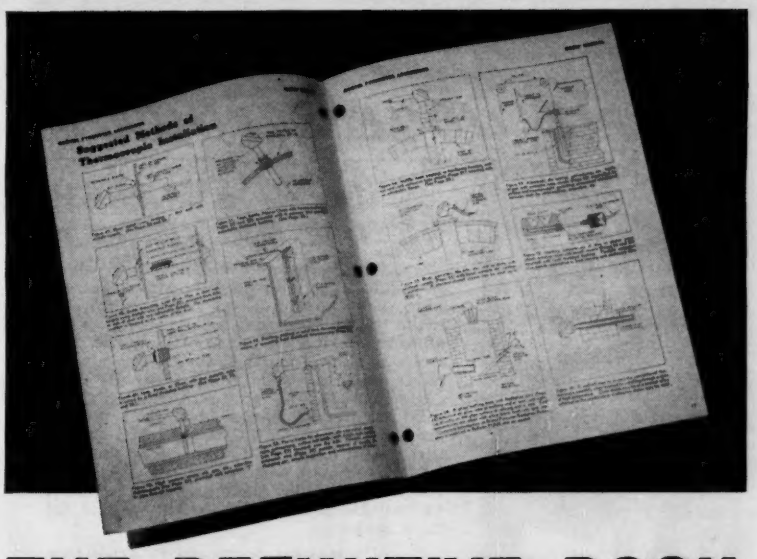
CIRCLE 339 ON READER-SERVICE CARD

MAGNETIC LEVEL GAGES



New Magnetic Liquid-Level Gages feature a unique safety design with the measuring device inside the stainless steel or other non-magnetic chamber. Indicating scale is mounted outside the chamber and is magnetically actuated through the chamber wall. Level indicator consists of edge-magnetized wafers which rotate. Gages are for liquid level or interface service.—*Jerguson Gage & Valve Co.*, 80 *Adams St., Burlington, Mass.*

CIRCLE 340 ON READER-SERVICE CARD



THE DEFINITIVE BOOK

on thermocouples and pyrometer accessories

It's still Bristol's big 56-page "Buyers' Guide and Users' Manual"—yours for the asking.

One of the most useful publications ever directed specifically to the industrial pyrometer user, this buyers' guide catalogs Bristol's comprehensive line of thermocouples, protection tubes, thermocouple wire and radiation unit accessories. But, in addition to this, it's a compendium of technical data for the pyrometer user—essential to newcomers to the field, valuable reference data to the old hand. Here's just a partial listing of topics discussed:

- Thermocouple types
- Factors affecting thermocouple life
- Thermocouple reproducibility
- Calibrated thermocouples
- Thermocouple insulation
- Thermocouple protecting tubes
- Thermocouple extension wires and cold-end compensation
- Selecting the right thermocouple and protecting tube
- Responsiveness of thermocouples

... plus more than 165 illustrations, plus 8 pages of thermocouple calibration tables. It's a manual you can't afford to be without. Write for your copy of Bristol's "Thermocouple and Pyrometer Accessories Buyers' Guide and Users' Manual," Bulletin No. P1238, today. The Bristol Company, 154 Bristol Road, Waterbury 20, Conn.

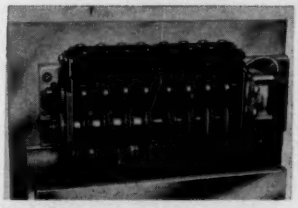
0.32

BRISTOL ... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

CIRCLE 152 ON READER-SERVICE CARD

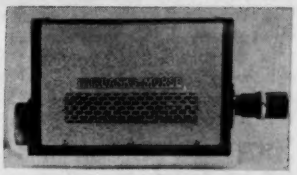
BEAD CHAIN TIMER



New Timer uses a drive sprocket with endless stainless-steel bead chain instead of cam to actuate switch. Microsecond timing and timing accuracy have been established. Available on a semi-custom basis.—*Eagle Signal Co.*, 202-20*th St., Moline, Ill.*

CIRCLE 429 ON READER-SERVICE CARD

INFRARED TV CAMERA



New infrared-sensitive Television Camera can "see" an object, such as a steel plate, when the object reaches 850°F, or a burglar prowling in the dark when the scene is illuminated by infrared lamps.—*Fairbanks, Morse & Co.*, 600 *S. Michigan Ave., Chicago* 5, *Ill.*

CIRCLE 430 ON READER-SERVICE CARD

Name your service!

ALLOY STEEL SERIES
Working pressures to 10,000 psi.
316 STAINLESS SERIES
Working pressures to 6,000 psi.
416 STAINLESS SERIES
Working pressures to 10,000 psi.
Ask for bulletins covering full line

. . . there's a MARSH NEEDLE VALVE for it

Three great series of needle throttling valves—designed and built as only Marsh experience *in both* valves *and* instruments can make them. In materials for extreme range of services. In a full range of sizes and patterns, including panel mounted. For a wide range of pressures and temperatures.

Body and stem guides machined from solid bar stock for extra strength. Precision ground stems with fine pitched stem-threads for close regulation—tight shut-off. Long lived, but easily replaced "Marpak" moulded packing; Teflon in stainless steel valves. Deep inlet and outlet threads for tight make-up.

MARSH INSTRUMENT COMPANY
Dept. 42, Skokie, Ill.
Division of Colorado Oil and Gas Corporation
Marsh Instrument & Valve Co. (Canada) Ltd., 8307 103rd St., Edmonton, Alberta, Canada. Houston Branch Plant 1121 Rockwell St., Sect. 15, Houston, Texas. Eastern Seaboard Warehouse: Marsh Instrument Company, 1209 Anderson Ave., Fort Lee, N.J.

CIRCLE 153 ON READER-SERVICE CARD

NEW! ELECTRONIC CONTROL METER

• Patent Nos. 2,871,450 and 2,967,278

MODEL 2547

WITHOUT ELECTRICAL CONTACTS provides continuous output signal past selected control setting, with uninterrupted, accurate full-scale indication at all times. No electrical contacts at control point, so no control-point problems. No undesirable feedback because indicating and transistorized switching circuits are completely isolated. No pull-in or locking coils or special power supplies required. Available in two standard models with single or double independent control-arm circuits. Both may be had with scales for horizontal or vertical mounting, with zero at center, left or right.

FOR ACCURATE INDICATION AND CONTROL IN:

Communications • Missile Checkout • Nucleonics • Signal Monitoring • Voltage Control • Process Control • Data Processing • Alarm Systems • . . . or wherever dependable, fail-safe control is required

WRITE FOR ENGINEERING DATA SHEETS on our complete line of panel meters, side indicators, Electronic Control Meters, miniature multitesters.

miniaturization headquarters
international instruments inc.
88 Marsh Hill Road, Orange, Conn., Cable "Interinst"

CIRCLE 154 ON READER-SERVICE CARD

FLOW MONITOR

New Flow Monitor for mass flow measurements of air or gas flow rates is a center-reading flowmeter featuring variable sensitivity and range adjustment by means of interchangeable flow tubes and control adjustments. Sensitivity increases to low flow rates. —*Hastings-Raydist, Inc., Hampton, Va.*

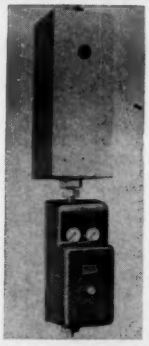
CIRCLE 341 ON READER-SERVICE CARD

GC SWEEP OSCILLATORS

New series of four Microwave Sweep Oscillators—including Model 682C, covering frequencies from 1.0 to 2.0 gc (kmc); Model 683C, 2.0 to 4.0 gc; Model 684C, 4.0 to 8.1 gc; and Model 686C, 8.2 to 12.4 gc—provide either a CW or swept rf output throughout their bands. Employ new backward-wave-oscillator tubes whose frequency is shifted by varying an applied potential.—*Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif.*

CIRCLE 342 ON READER-SERVICE CARD

TRANSMITTING ROTAMETERS



New Series 3613 Transmitting Rotameters for superpressure flows up to 50,000 psi are "first variable-area-type flowmeters offered for superpressure services; allow direct measurement of high-pressure flows previously considered unmeasurable." In four sizes from 0.90 to 47.0 gpm; installing meter in bypass with orifice plate in main pipeline permits higher capacities. Bulletin 830.—*Brooks Instrument Co., Inc., W. Vine St., Hatfield, Pa.*

CIRCLE 343 ON READER-SERVICE CARD

DIG/AN CONVERTER

New-transistorized Type 1134-A Digital-to-Analog Converter is an element in the new GR system of graphic frequency recording with the Type 1130-A Digital Time Frequency Meter. Input represents the four, continuously-displayed digits of the counter readout, output is a negative d-c analog current, corresponding to either two or three of these four digits, for driving a d-c recorder. Accuracy is 0.1%.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

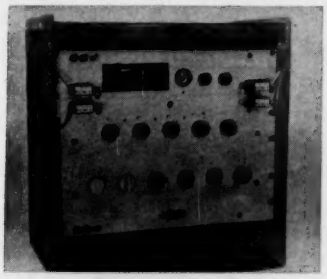
CIRCLE 344 ON READER-SERVICE CARD

PRECISION METERS

New "Selective-Expansion" Meters guarantee electrical measurements with 0.025% accuracy by electrically folding an effective 5-foot scale into 10 equal sections, each 6" long. Thus the third significant figure can be read exactly, and fourth figure estimated to ¼ division. Useful as laboratory standard.—*Greibach Instruments Corp., 315 North Ave., New Rochelle, N. Y.*

CIRCLE 345 ON READER-SERVICE CARD

CAPACITANCE MEASUREMENT



New Model 700 Capacitance Measuring System measures 2- or 3-terminal capacitors in the range from 0 to 0.12 μf with a resolution of 0.0001 pf on the lowest range. Bridge provides 5 ranges of capacitance readings with 120,000 dial divisions of resolution on any range. Accuracy relative to the standard capacitor at frequencies between 100 and 1000 cps is ±0.01% plus one dial division on the 3 intermediate ranges; ±0.02% plus one dial division on the highest and lowest ranges.—*Electro Scientific Industries (formerly Electro Measurements), 7524 S. W. Macadam Ave., Portland 19, Ore.*

CIRCLE 346 ON READER-SERVICE CARD

NEW

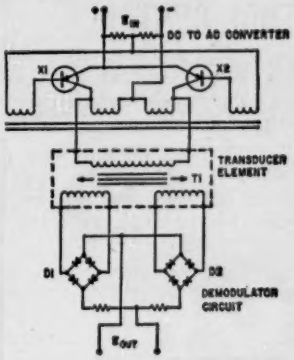
DIRECT CURRENT

DISPLACEMENT TRANSDUCER

SPECIFICATIONS

Type:	LVDT
Scale Factor:	120 V/in DC
Stroke:	±0.10 in.
Linearity:	0.5% full scale
Static Resolution:	∞
Dynamic Response:	> 500 CPS
Temp. Range:	−65° F to +250° F
Excitation:	24VDC

Construction: Magnetically shielded; pressurized for direct insertion into hydraulic fluid; threaded case with nylon lock; threaded probe shaft.

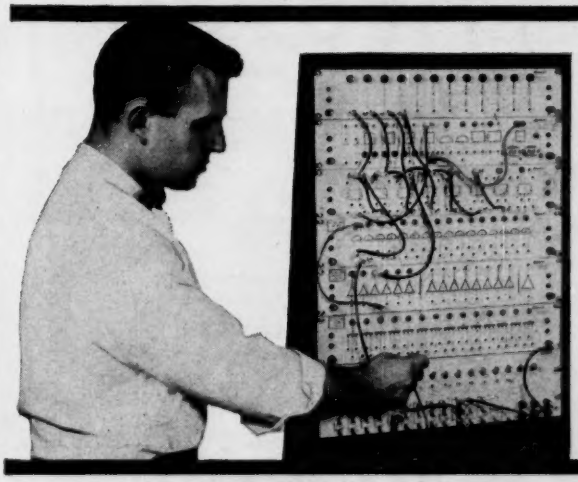


G. L. COLLINS CORPORATION

2820 EAST HULLETT ST. LONG BEACH 5, CALIF.

METCALF 0-3121—TWX: CPT-6009

CIRCLE 158 ON READER-SERVICE CARD



TYPES OF EPSCO LOGIC PANELS

Flip Flops
Diode Gates
Transistor Gates
Amplifiers
Emitter Followers
Timers
Indicators
Switches
Test Panel

LOGIC DIAGRAMS TO PROTOTYPES IN HOURS . . . WITH NEW LOGIC PANELS Epsco's 16 compact new Logic Panels put the entire range of digital circuits at your fingertips, for simple, rapid patchcord connection. Save time and money in logic bread-boarding . . . small system construction . . . programmable test, control and timing equipment . . . logic demonstration and instruction. One basic set of panels can be used again and again. Complete flexibility allows designer to change or update his circuitry at any time. All circuits are labelled with bold logic symbols. Instant access to inputs, outputs, and power connections. Once a system is proved out, identical circuits can be ordered off-the-shelf from Epsco. For full details, contact Epsco. Ask for Bulletin TDC-LP1.

Epsco COMPONENTS

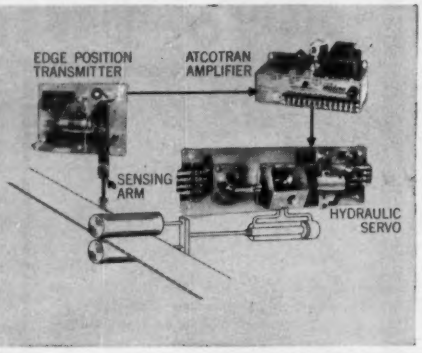
A Division of Epsco, Incorporated, 275 Massachusetts Ave., Cambridge 39, Mass.

CIRCLE 156 ON READER-SERVICE CARD

DISPLACEMENT PICK-UPS FOR MACHINE AUTOMATION

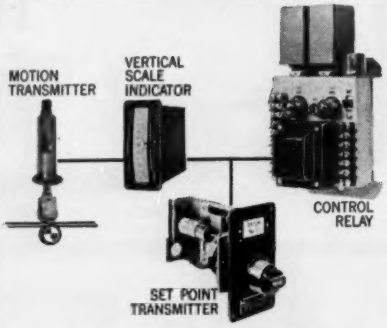
EDGE CONTROL

Atcotran Edge Guide Control maintains constant, precise edge positioning (within 0.001") for accurate register of moving web. Range is 2¼" with only ¼ oz. pressure on edge. Stable null balance circuit. For paper, metals, textiles, plastics, etc.



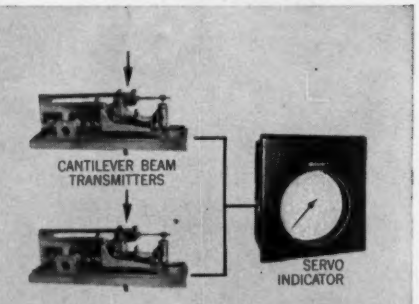
THICKNESS MEASUREMENT

ATC measuring devices for reliable automation control systems. Indicates and controls thickness to adjustable pre-set tolerance. Ideal for wallboard, sheet metal, plywood, plate glass, etc.



WEIGHT SUMMATION

ATC Cantilever Load Cells change force (or weight) to electrical signal, recorded as weight on servo indicator. Multiple load cells may be algebraically coupled for indication-control of force, thrust, torque, etc.



ADVANCED DIFFERENTIAL TRANSFORMER PRINCIPLE permits simple and rapid automation of machine functions using standard off-the-shelf control components, indicators, recorders, and process controllers. Discuss your applications and requirements with your ATC representative.

Send for literature on Atcotran Differential Transformer Experimental Kit—today!

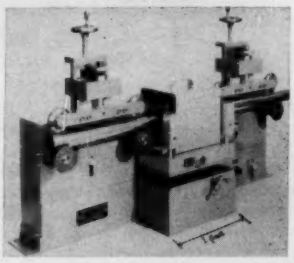
atc

AUTOMATIC TIMING & CONTROLS, INC.
KING OF PRUSSIA, PENNSYLVANIA
A Subsidiary of American Manufacturing Company, Inc.

ATC, Div. of Interprovincial Safety Industries, Ltd., 5485 Notre Dame St., West, Montreal 30, Quebec

CIRCLE 157 ON READER-SERVICE CARD

TUBING AND BAR STOCK FEEDERS



Two new drive units feed round tubing and bar stock, work with eddy current tests to locate defects in ferrous or non-ferrous products. Type X-2316 handle diameters from ¼" to 4" at 40 to 400 fpm. Type X-2366 feeds diameters from ¼" to 1-½" at 180 or 300 fpm (other speeds by changing pulley sizes).—*Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill.*

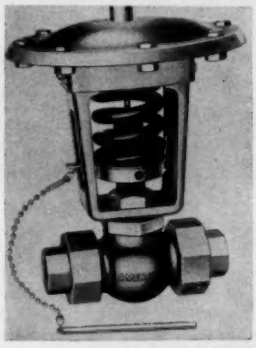
CIRCLE 347 ON READER-SERVICE CARD

DEVIATION TESTER

New microwave Stability Tester, Model 5024 measures frequency variations as small as 1.5 parts in 10 billion and features wide dynamic range and small size. It displays FM deviation from a minimum full-scale rate of 10 cps to a maximum of 30 kc. Ranges are 10; 30; 100; 300; 1,000; 3,000; 10,000; and 30,000 cps. Microwave plug-in heads are available for S- and L-band, C-band, X-band, and X-band upper range.—*Laboratory for Electronics, Inc., 1079 Commonwealth Ave., Boston 15, Mass.*

CIRCLE 348 ON READER-SERVICE CARD

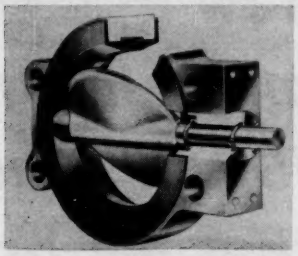
PRESSURE REGULATORS



New line of Pressure Regulators features a friction-free packless valve. Good for steam, air, water, and gases that are non-corrosive to bronze, iron, or neoprene. Available single seated and double seated in sizes from ½" through 2". Other features include bellows-equipped valve stem, disc and seat rings. Bulletin 116.—*Manning, Maxwell & Moore, Inc., Stratford, Conn.*

CIRCLE 349 ON READER-SERVICE CARD

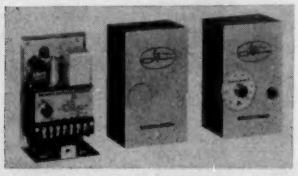
BUTTERFLY VALVE



New Butterfly Valve, the Double R/L, is for bubble tight shut-off on vacuum service and differential pressures up to 150 psi, at temperatures from −60° to 400°F. Sizes: 2" through 12". Valve never needs lubrication. Bulletin 91.—*Continental Equipment Co., 200 Main St., Coraopolis, Pa.*

CIRCLE 350 ON READER-SERVICE CARD

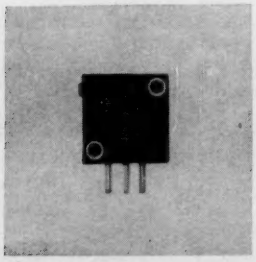
TEMPERATURE CONTROL



New 7000 Series electronic Temperature Controls feature plug-in "Anticipator" to anticipate set-point on proportional basis, actuate relay; ranges from −300° to 2000°F accurate to ±0.3°F; control circuit encapsulated in epoxy to withstand shock,, vibration, dust, etc. Available in 20 models.—*Electronic Processes Corp., 436 Bryant St., San Francisco, Calif.*

CIRCLE 351 ON READER-SERVICE CARD

SUBMIN POT



New Model 357 Squaretrim (TM) Subminiature Potentiometer for high-temperature printed circuit applications is ½" x ½" w x 0.2", gives resistance values from 10 ohms to 50 kohms over an operating temperature range from −55° to +200°C. Features include circular design of the mandrel, 30% more turns for one complete sweep of the wiper, and up to twice the resolution of ordinary trimmers. Resolution at 50 ohms is stated as 0.086%.—*Daystrom, Inc., Potentiometer Div., Archbald, Pa.*

CIRCLE 352 ON READER-SERVICE CARD

New MANOSTAT Linear Electroplating Analyzer

Solves electroplating problems quickly, easily, with simple DIRECT CALCULATION

Usual types of electrolytic analytical cells depend on empirical methods which are often unsatisfactory. This new Linear Electroplating (Cell) Analyzer by MANOSTAT simplifies study in the lab and in the field by enabling you to make direct linear calculations. When employed in the control, development and study of plating solutions, the Analyzer cell gives linear distribution along the electrode so that calculations can be made from simple measurements. The unit is fabricated of Plexiglass (II-A) to fine tolerances. The two sides holding the electrodes are opaque, the other two clear to permit unobstructed observation.

Royalties from the sale of the Linear Electroplating (Cell) Analyzer, U.S. Patent No. 2,913,375, go to the Polytechnic Institute of Brooklyn for their aid in its successful development.

PC1000 – Linear Electroplating Analyzer, consisting of Plexiglass cell and cover only **$29.50**

See your local laboratory supply dealer.

MANOSTAT Corporation
26 N. MOORE ST., NEW YORK 13, N.Y.

CIRCLE 155 ON READER-SERVICE CARD

INSTRULAB'S
Temperature Compensated
evenvolt
Constant Voltage Unit

Replaces Batteries and All Standardizing Components Including Standard Cell in
POTENTIOMETERS
• CONTROLLERS • INDICATORS
• RECORDERS

Mfg. By
INSTRULAB, INC.
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Dayton 4, Ohio
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Outstanding FEATURES
- Eliminates batteries ...errors due to battery exhaustion
- Reliable construction...from quality components, long, trouble-free service
- A Precise voltage regulator . . . max. ±.04% for ±20% voltage variation
- Quickly Installed... Fits present instrument battery space.
- No Tubes to replace

CIRCLE 159 ON READER-SERVICE CARD

FIRST AND ONLY
RECORDING pH METER

Permanent pH Record • Simple to Operate • Adaptable • No Ink

A pH meter and strip chart recorder in one. Line operated. Continuously indicating. Can record continuously for 31 days at one inch per hour. 0-14pH. With automatic temperature compensator. Write for Bulletin No. 3R.

Price $245.00 complete, with Analytical protected pH probe unit

ANALYTICAL MEASUREMENTS, INC.
585 Main Street
Chatham, New Jersey

CIRCLE 160 ON READER-SERVICE CARD

PHOTOTRON

FIRST IN NEW LINE OF ANALOG TO DIGITAL CONVERSION PRODUCTS FROM HYDRO-AIRE

This highly versatile basic transducer offers incremental conversion of shaft angle to digital measurement. Available in seven models, its maximum permissible speeds range from 15,000 rpm at 128 counts per revolution to 1,250 rpm at 2,048 counts, with sample rates ranging to 45,000 counts per second.

Applications for the Hydro-Aire Phototron include analog to digital shaft converters, precision analog servo with digital readout, data reduction equipment, tachometers, and precision measurement and control.

Detailed specifications are available on request. Related products soon to be available from Hydro-Aire, a member of the Crane Co. Systems and Controls Group, will include associated power supplies and binary and digital counters.

HYDRO-AIRE

3000 WINONA AVE., BURBANK, CALIF.

DIVISION OF CRANE CO.

Solid-state devices include time delay devices, voltage regulators, power supplies, inverters.

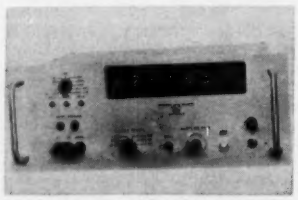
CIRCLE 161 ON READER-SERVICE CARD

CABLE IDENTIFIER

New Coded Impulse System provides cable and phase identification. Consists of Model XPT-100 Cable and Phase Identifier Transmitter with capacitor discharge and battery-operated, transistorized detector, Model XPI-100. Identification is made by applying a series of coded directional electrical impulses to the cable conductors at an up-line terminal, where identity and phasing is known. These coded impulses are picked up at the splice location by means of a zero-center meter actuated by a detecting coil positioned over the cable.—*Davenport Mfg., Div. Duncan Electric Co., Inc., Dept. 1A-5, N. Elston Ave., Chicago 47, Ill.*

CIRCLE 353 ON READER-SERVICE CARD

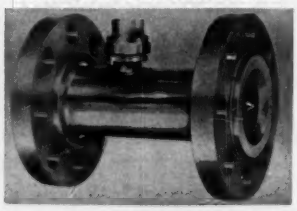
DIGITAL VOLTMETER



New integrating Digital Voltmeter, Model DY-2401, reads average value of voltage applied over a definite, selected sample period. Noise and hum effects are eliminated. Five voltage ranges from 0.1 to 1000 v nominal full scale. Stability is better than 0.01%/day; overall accuracy is 0.05% nominal. Bulletin 2401.—*Dymec, Div. of Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.*

CIRCLE 354 ON READER-SERVICE CARD

TURBINE FLOWMETERS



New series of Turbine Flowmeters is available in 12 sizes from 5 to 12,000 gpm with linearity of 0.05% of flow. Fabricated of stainless steel with standard ASA or split-ring flanges. Operating pressures: to 3000 psig at temperatures from −455° to 500°F with pressure drop of approximately 4 psi. Individually calibrated on weigh-time calibrators correlated with flow standards of NBS. Bulletin 1384B-2.—*Cox Instruments Div. of George L. Nankervis Co., 15300 Fullerton, Detroit 27, Mich.*

CIRCLE 355 ON READER-SERVICE CARD

new multi-range 190° c. span thermistor based tele-thermometer

Model 42 Price $125.00

Major Features

- Temperature range: −40° to 150° C. or −40° to 302° F.
- Direct reading of temperatures in three overlapping ranges:

Model 42SC	Model 42SF
−40° to 30° C.	−40° to 86° F.
20° to 80° C.	68° to 176° F.
70° to 150° C.	158° to 302° F.

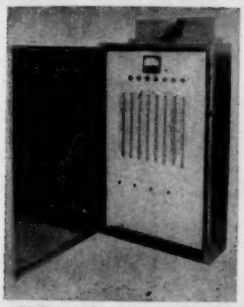
- Absolute accuracy of ± 0.5° C. and ± 1.0° F. except at temperature extremes.
- Interchangeable probes—any YSI 400 series.
- Remote, continuous monitoring.
- Portable, weighs only 3¼ lbs.

Get complete specifications from your YSI dealer or write:

YELLOW SPRINGS INSTRUMENT CO., INC.
Yellow Springs, Ohio

CIRCLE 162 ON READER-SERVICE CARD

COMPUTER-CONTROLLER



New CM-3 solid-state Analog Computer-Controller provides real time control for fractionating towers, butadiene processing, and other multivariable chemical and petro-chemical processes. Modular construction allows custom units for each application. Over-all accuracy can be as good as ½%.—*Dresser Electronics, SIE Div., Box* 22187, *Houston* 27, *Tex.*

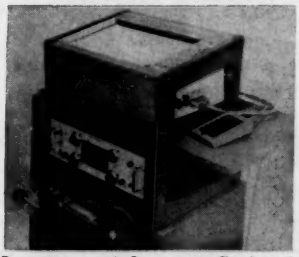
CIRCLE 356 ON READER-SERVICE CARD

DIGITAL STRAIN INDICATOR

New Model 416 Digital Strain Indicator, a calibration instrument for strain gage bridges, features high linearity, high resolution, high slewing speed, simplicity of operation, and a self-contained, variable bridge excitation voltage. Applications include monitoring of strain-gage load-cells and strain-gage instrumentation.—*Dynametrics Corp., Northwest Industrial Park, Burlington, Mass.*

CIRCLE 357 ON READER-SERVICE CARD

DIGITAL PLOTTER



New compact low-cost Series 3100 Dataplotter converts data from any digital computer system to graphic displays. Accepting analog or digital inputs, it provides accuracies up to 0.175% of full scale in 11" x 17" X-Y plots of digital data and permits plotting speeds up to 80 points/min. Equipped with transistorized control circuitry, provisions for "off-board" origin, it receives punched card, tape or keyboard input.—*Electronic Associates, Inc., Long Branch, N. J.*

CIRCLE 358 ON READER-SERVICE CARD

TANK CONTENTS AT-A-GLANCE with Dial-Type Liquidometer Gauges

For added assurance of accurate liquid quantity record keeping, specify easy-to-read Liquidometer gauges. Positive dial-and-pointer type indicators help to prevent erroneous readings . . . speed record keeping by showing tank contents at-a-glance.

Liquidometer gauges are available to measure and indicate virtually any liquid – at the tank site or remotely. Also available: integral or separate liquid level switches for automatic level warning or control. Float, hydrostatic, electric, or electronic operation can be supplied to meet your specific needs.

Let Liquidometer's forty years of experience in liquid level gauging and control work for you. Write for latest literature.

LIQUIDOMETER INSTRUMENTS

THE LIQUIDOMETER CORP.

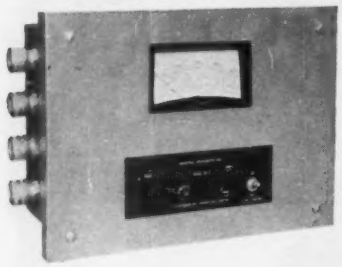
Dept. E, LONG ISLAND CITY 1, NEW YORK

CIRCLE 163 ON READER-SERVICE CARD

new

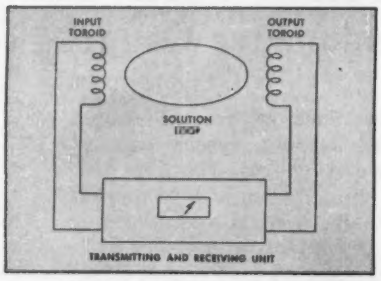
ELECTRODELESS CONDUCTIVITY MEASURING SYSTEM

Improved performance at lower cost



The Type RS electrodeless conductivity measuring system was first introduced by Industrial Instruments Inc. in 1957. Since that time many applications formerly difficult, if not impossible, for conventional electrode systems have been successfully instrumented by the system. This new system supplements standard techniques (Wheatstone Bridge circuit and electrodes in solution) and is recommended for conditions where the presence of fibers tends to clog conventional conductivity cells, or for abrasive slurries, hot highly conductive solutions, or extremely corrosive solutions.

A continued program of development has resulted in a number of improvements in both the cell, and the transmitting and receiving units. These design changes have also lowered the initial cost of the equipment, permitting its use in areas where cost has previously been a limiting factor.



The single electronic package contains both transmitter and receiver and incorporates a direct-reading meter. The instrument provides a stable 0-10 mv DC output for operating a standard potentiometer recorder or recorder-controller. Available to meet explosion-proof requirements.

Industrial Instruments

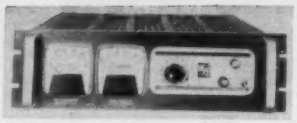
Write for complete details

Industrial Instruments Inc.

89 Commerce Road Cedar Grove, Essex County, N. J.

CIRCLE 164 ON READER-SERVICE CARD

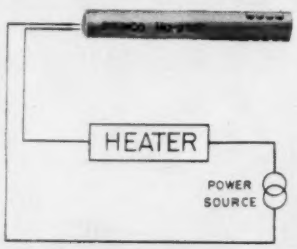
DC SUPPLY



New Model CR-18-30 controlled rectifier DC Power Supply provides up to 18 v at 30 amp in 7" panel. Features include ±0.01% or ±1 mv load regulation, 0.003 v peak-to-peak ripple, 40 μsec recovery time, remote sensing, remote programming stability of ±5 parts per 10,000 per 24-hour day, voltage adjustment resolution better than 5 mv.—*NJE Corp., 20 Boright Ave., Kenilworth, N. J.*

CIRCLE 359 ON READER-SERVICE CARD

PRECISION THERMOSTAT



New MU-STAT, a miniaturized, liquid-in-glass thermostat offers direct switching of 1, 4.7, 10 amp or larger current loads without external relays or amplifiers, handles output voltages up to 400 v and frequencies from 25 to 1000 cps, readily achieves internal power gains of one million, yet only 85 μamp pass through the mercury column to switch a 1-amp current. Setting accuracies to 0.1°C and differential of 0.05°C can be provided.—*Precision Thermometer & Instrument Co., 1434 Brandywine St., Phila, 39, Pa.*

CIRCLE 360 ON READER-SERVICE CARD

NOISE ANALYZER

New transistorized Amplitude-Distribution Analyzer, Model 317, establishes amplitude-probility distribution of random signals, can determine threshold requirements, error or false alarm probabilities, etc. Operates over a frequency range from 5 cps to 0.5 mc. Amplitude ranges are 100%, 10% and 1% full-scale. Accuracy is ±3% full scale.—*Quan-Tech Laboratories, Inc., 60 Parsippany Blvd., Boonton, N. J.*

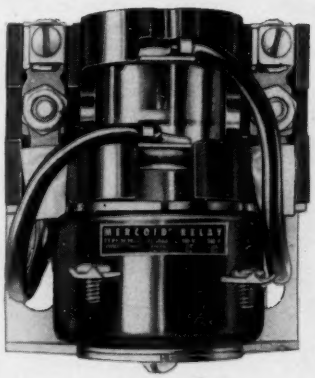
CIRCLE 361 ON READER-SERVICE CARD

35 AMP

* 120V. Non-Inductive A.C. heater loads

Plunger Type

MERCURY RELAY



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If you need reliability and durability, this quality built relay by Mercoid is your answer.

For heavy duty loads, such as resistance heating, (domestic, commercial, industrial)—heat treating furnaces, drying equipment, welding, lighting, illuminated signs, score boards.

Hermetically sealed mercury to mercury contact provides visible on-off operation. Silent and chatterless. Quickly mounted, easily wired. Speeds up to 100 operations per minute.

Available normally open;

CONTACT RATING:

LOAD			*NON INDUCTIVE HEATER LOADS	
	AC	DC	AC ONLY	
120V.	30A.	15A.	120V.	35A.
240V.	20A.	10A.	240V.	25A.
440V.	8A.	—	440V.	10A.

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THE MERCOID CORPORATION

4211 Belmont Ave., Chicago 41, Ill.

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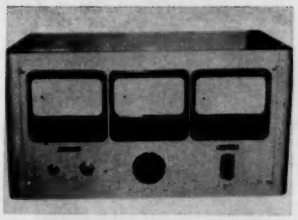
offers the world's most complete line of optical recording oscillographs, so that you may choose a model to meet your specific data recording needs. 32 different models of direct-writing and standard photo process recorders, **in full production and field proven,** allow a combination of functional features and performance to meet the most critical requirements.

MI oscillographs are now being used in some of the most complex R & D data recording systems. Other uses include environmental testing, production, medical and educational applications. **Several thousand** of the rugged 560 are being used for "on-board" recording in rockets, missiles, torpedoes and test sleds.

Write Dept. ICS

CIRCLE 166 ON READER-SERVICE CARD

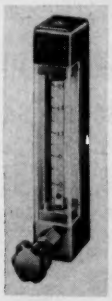
AC/DC TEST SET



New high-capacity a-c/d-c Test Set, Model KSI-50 features both a-c and d-c output channels with separate 4" voltmeters for a-c rms and dc, plus a common a-c/d-c current meter. Output is continuously adjustable from zero to maximum; current capacity is 50 ma ac and 25 ma dc. Includes heavy duty 100-ma circuit breaker with trip-free reset.—*Peschel Electronics, Inc., Towners, Patterson, N. Y.*

CIRCLE 362 ON READER-SERVICE CARD

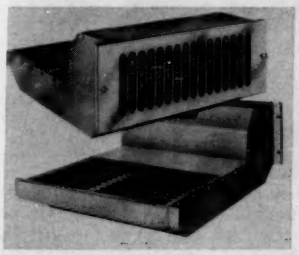
FLOWMETER



New Model 125 Flowmeter for purge and low flow applications features interchangeable tubes, rigid body and integral characterized needle valve with stainless steel or glass floats. Unit has range of 0.2 to 90 scfh air and 0.05 to 20 gph water.—*Devco, Inc., Box 374, Hatboro, Pa.*

CIRCLE 363 ON READER-SERVICE CARD

TWO-SPEED BLOWER

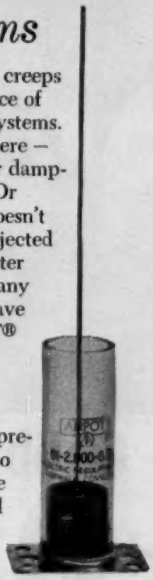


New 19-inch, 500-cfm Centrifugal Blower is said to yield greater air turbulence over the entire rack interior for faster and more efficient dissipation of heat around tubes, semiconductors, sensitive components. Motor is 60-cycle, 115-v unit. Bearings are double sealed.—*McLean Engineering Labs., Princeton, N. J.*

CIRCLE 364 ON READER-SERVICE CARD

When the **UNPREDICTABLE** *happens*

• • • the kind that creeps into the performance of newly completed systems. (Excess vibration here — slight time delay or damping needed there. Or perhaps stability doesn't match the data projected on paper.) To counter these variations, many of our customers have found the AIRPOT® an inexpensive problem solver.



AIRPOT is an air-damping dashpot; precisely constructed to operate within close tolerances. Its small size will rarely disturb a system's basic design.

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Series 120000

Features:
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- Quick disconnect at rear for easy lamp replacement.

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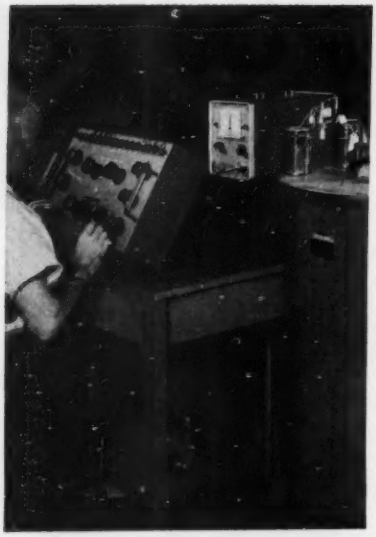

Calibrate to ±0.3 C*

with L&N Precision Checking Equipment

Growing emphasis on accuracy of temperature measurements has probably focused your attention on the need for precision equipment for thermocouple calibration.

Power plants, for instance, have found that they can substantially decrease fuel costs when turbine thermocouples are checked regularly for accuracy. In brazing processes for aircraft and missiles, where a 1.0 F variation is critical, thermocouple calibration is vital to the entire operation.

In the installation shown above, individual thermocouple wires are being checked against a platinum reference standard. The equipment consists of a:

9003 Checking Furnace	$750.00
CF-19S Alloy Equalizing Block	356.00
7553 Type K-3 Potentiometer	730.00
9834 D-C Null Detector	295.00
7308 Standard Cell	36.00
7597 Battery	23.00

Prices subject to change without notice

For more information about this equipment, contact your nearby L&N office, or write Leeds & Northrup Company, 4955 Stenton Avenue, Philadelphia 44, Pa.

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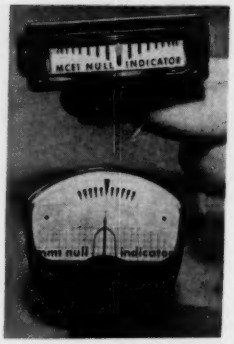
NULL INDICATORS



New miniature and edgewise Null Indicator MM-1 (Medalist) and MOE-1 (edgewise) employ core magnet, self-shielded mechanisms in unique structures providing high sensitivity at the null point and sharp square-law attenuation as the pointers deflect from center. Available with sensitivities of ½, 1, and 2 μamp at null point, with end scale values of 100, 200 and 500 μamp.—*Minneapolis-Honeywell, Precision Meter Div., Grenier Field, Manchester, N. H.*

CIRCLE 365 ON READER-SERVICE CARD

PRESSURE GAGE

New Safe-T-Kase gage has integrally-cast solid wall which separates the Bourdon tube assembly from the ring, safety glass, and dial. Back of case is covered by spring mounted pressure-releasing plate. Less than ½ psi pressure will force the plate open. In the event of tube rupture, the pressure medium is discharged out of the back of the case, away from operating personnel. Available as C-15 back flange style of C-154 flush mounted in 4½", 6" and 8½" sizes.—*J. E. Lonergan Co., 211 Race St., Phila. 6, Pa.*

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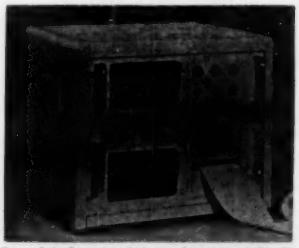
DATA LOGGER



New high-precision Automatic Data Logger (RS2) provides 4-digit voltage readings with correct polarity and range. Has 2 digits for inputs channel identification. Accuracy is 0.01% of full scale on each range. Functions include: scanning up to 20-double-pole channels; measuring d-c voltage from ±0.001 to ±999.9 in ranges of ±9.999/99.99/999.9; printing channel number; 4-digit reading, polarity and decimal point placement.—*Non-Linear Systems, Inc., Del Mar, Calif.*

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20 important features to consider

- ½% accuracy
- Standard 8½"x 11' graph paper
- Flat bed
- 7½ in/sec. pen speed
- Clip on pens for multicolor trace
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- Drift free
- Continuously variable attenuators
- Each axis mechanically & electrically independent
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- Full chart visibility
- Floating inputs to 100 volts dc
- Interchangeable chopper stabilized amplifiers
- Inline simplified control panel
- 10 or 1 mv/in sensivity
- 10 k or potentiometric input
- Unobstructed paper loading
- Completely portable (35#—14" x 15" x 8")

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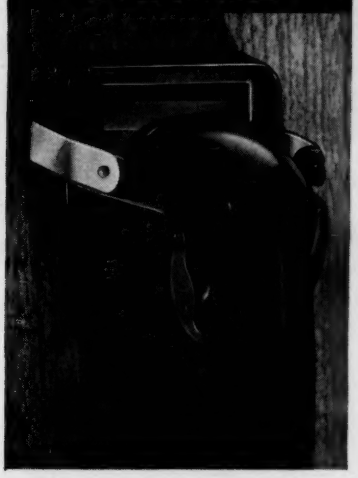
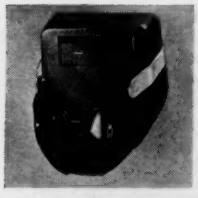
NEW STROMBERG-CARLSON TELEPHONE HANDSET CRADLE



... for positive retention in all mobile applications

There's no jump, no sway—when a telephone handset is in the firm grip of this new Stromberg-Carlson® handset cradle.



Retaining clip spring assembly assures positive retention in any mobile application on land or sea, or in the air. Even extremely severe jars, jolts and vibrations fail to dislodge the handset.

The cradle is strong and resilient, fits any Stromberg-Carlson handset. Different models provide varying switch combinations with 2 or 4 Form C contacts. All models available with or without the clip assembly.

Details on request from these Stromberg-Carlson offices: Atlanta —750 Ponce de Leon Place N.E.; Chicago—564 W. Adams Street; Kansas City (Mo.)—2017 Grand Avenue; Rochester—1040 University Avenue; San Francisco—1805 Rollins Road.

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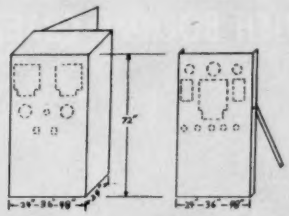
STOCK CUBICLES AND PANELS



New line of Stock Size Cubicles and Panels made from heavy-duty #10 Ga steel is prime coated. Sizes available are 72" high x 24" deep, and 24", 36", and 48" widths.—*Armesco, Inc., Lansing & Bingham Sts., Phila.* 11, *Pa.*

CIRCLE 368 ON READER-SERVICE CARD

QUALITY MAGNETIC TAPE

New high quality Recording Tape has signal output strength regulated to less than ½ db of variance. Tape uses special acicular iron oxide powder filtered down to particle size of 5 μ or less. Acetate or Mylar plastic base. Produced in ¼" widths and marketed in all standard reel lengths. —*Burgess Battery Co., Div. Servel, Inc., Freeport, Ill.*

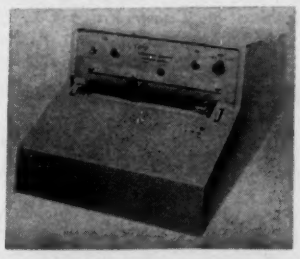
CIRCLE 369 ON READER-SERVICE CARD

LOGIC MODULES

New S-Blocs for the One-Mc 3C-PAC Series S plug-in digital modules, accommodate either 19 or 28 S-Pacs; 20 labelled test points are provided—*Computer Control Co., Inc., 983 Concord St., Framingham, Mass.*

CIRCLE 370 ON READER-SERVICE CARD

ABSORPTIVITY RECORDER



New Model 2015 Absorptivity Recorder for operation with Cary Spectrophotometers records absorptivity (extinction coefficient) on a logarithmic scale. Provides spectra whose shape is unaffected by sample concentration of pathlength. Has a five-decade scale. Chart speeds are ½, 1, 2, 4 and 5 ipm.—*Applied Physics Corp., 2724 S. Peck Rd., Monrovia, Calif.*

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BOARDMASTER VISUAL CONTROL

- ☆ Gives Graphic Picture—Saves Time, Saves Money, Prevents Errors
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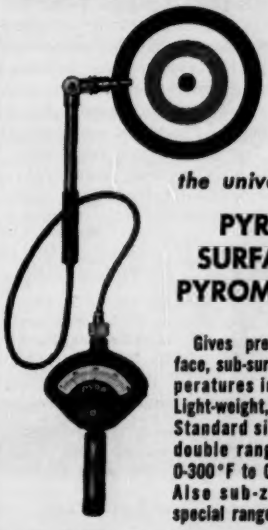

the universal

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Gives precise surface, sub-surface temperatures instantly. Light-weight, rugged. Standard single and double ranges from 0-300°F to 0-1500°F. Also sub-zero and special ranges.

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BERGENFIELD 4, NEW JERSEY

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HIGHLY ACCURATE

MOISTURE ANALYSIS

The new compact Moisture Teller No. 277 reaches a preset drying temperature faster than any similar unit available today. High static pressure from a high speed blower *removes free moisture in any material*—solid, granular, liquid or semi-liquid. Produces an absolute analysis. No calibration required. A real aid to quality and cost control in processing foodstuffs, fibres, chemicals, soaps and many other materials.

12 Page Catalog

sent on request. Ask for bulletin SL-1. Describes complete line of moisture tellers, drying ovens, speed desiccators, etc.

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CONTROL EQUIPMENT
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CIRCLE 174 ON READER-SERVICE CARD

PRECISION IS SYNONYMOUS WITH BOEHME CRAFTSMANSHIP

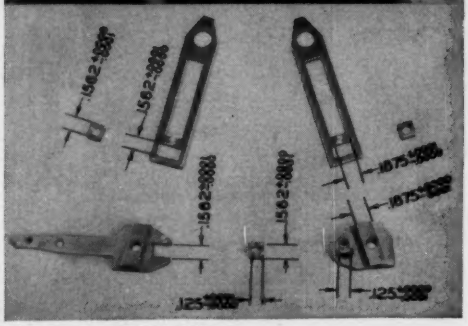
Precision is our business. We have been pioneers in the engineering, design, and manufacture of the precision demands in the field of Instrumentation and Automation.

The parts shown in the figure, held to the tolerances indicated, are typical examples of Boehme skill in precision craftsmanship.

Any or all of our precision production facilities are available to you. Write or call us, there is no obligation.

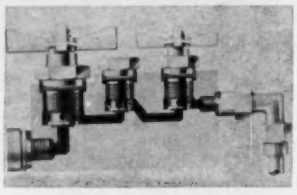
H. O. Boehme, Inc.

Contractors, Designers, Manufacturers of Precision Electrical, Electro-Mechanical and Electronic Equipment since 1917
915 Broadway
New York 10, N. Y.



CIRCLE 175 ON READER-SERVICE CARD

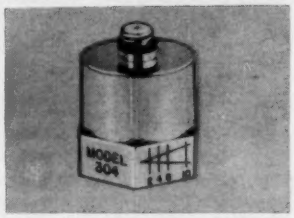
O-SEAL CARTRIDGE INSERTS



New O-Seal Valve Cartridge Inserts are said to assure bubble-tight shut-off at pressures to 6000 psig in manifolds at valve seats, around the stem and bonnet. Sizes: ⅛" to 2".—*Combination Pump Valve Co., Dept.* 117, 851 *Preston St., Phila.* 4, *Pa.*

CIRCLE 372 ON READER-SERVICE CARD

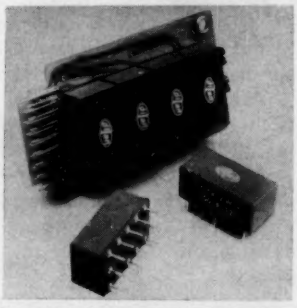
STANDARD ACCELEROMETER



New true compression Accelerometer, Model 304, for shock and vibration applications has long term stability which makes it especially suitable as a transfer standard with periodic NBS calibration. Nominal sensitivity is 50 mv/g and frequency response is flat within ±5% from 0.09 cps to 10 kc; resonant frequency is 55 kc. Acceleration range of the device is from 0.02 to 40,000 g with a maximum cross sensitivity of 5%.—*Columbia Research Lab., MacDade Blvd. & Bullens Lane, Woodlyn, Pa.*

CIRCLE 373 ON READER-SERVICE CARD

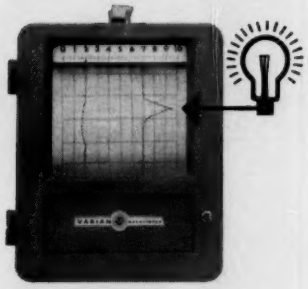
SHIFT ELEMENTS



New Model CTR 2W-100-P-12 Two-Way Shift Elements are solid-state asynchronous dynamic devices consisting of a single magnetic core, diodes, transistors, and associated passive components, encapsulated in a sealed epoxy. Permit shift pulse rates from 0 to 100 kc on either of the two shift lines. Application include bi-directional shift register, matrix register, multi-reading register.—*DI/AN Controls, Inc., 40 Leon St., Boston 15, Mass.*

CIRCLE 374 ON READER-SERVICE CARD

VARIAN
Potentiometer
RECORDERS
Offer exceptional
versatility because...



THERE ARE ACCESSORIES FOR

ALARM/CONTROL

Alarm and control switches, and retransmitting slide wires, add a valuable dimension of simple control to the already-versatile two-channel G-22. With these optional accessories they can work unattended to control two variables within the 1% accuracy of the recorder, while making a permanent record of what has happened.

1% accuracy, spans from 10 mv to 500 v, 1 second full-scale balance time, two chart speeds standard, four optional (½"/hr. to 16"/min.), full scale zero adjust, event markers and other options. Portable and rack-mounted models available from $1,075. Write Instrument Division:

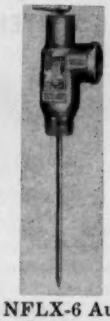
VARIAN associates
PALO ALTO 27, CALIFORNIA
CIRCLE 176 ON READER-SERVICE CARD

SOLID-STATE MODULES

New built-in-place BIPCO™ Modular Devices in modular form, said to cost a fraction of the cost of conventional circuit techniques, performs functions normally requiring myriads of elements and connectors. First module available is a Binary Coded Decimal-to-Decimal Converter using the 4-2-2-1 code. Uses silicon diodes and drives a NIXIE indicator tube directly from inputs encoded in the binary coded decimal form.—*Burroughs Corp., Electronic Tube Div., Box* 1226, *Plainfield, N. J.*

CIRCLE 375 ON READER-SERVICE CARD

RELIEF VALVES



New Type NFLX-6 Automatic Temperature and Pressure Relief Valve series for hot water storage tanks features a new and improved "pencil-thin" 6-inch thermostatic element. Available in ¾" and ½" sizes. Bulletin 1-NFLX-1.—*A. W. Cash Valve Mfg. Corp., (Cash-Acme) Box* 191, *Decatur, Ill.*

CIRCLE 376 ON READER-SERVICE CARD

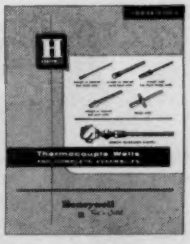
PRESS AND FLOW REGULATORS

New series of Pressure and Flow Regulators includes Model R 4009 pressure regulator, suitable for supply pressures to 150 psig, which maintains outlet pressure with ±0.25% accuracy, despite varying inlet pressure or flow. Has fingertip micrometer adjustment repeatability is ±0.5%. Model R 4003 flow regulator for flow ranges from 5 to 300 scfh maintains constant flow rate with varying inlet and outlet pressures.—*Circle Seal Products Co., Inc.,* 2181 *E. Foothill Blvd., Pasadena, Calif.*

CIRCLE 377 ON READER-SERVICE CARD

THERMOCOUPLE WELLS

Nine basic types of standard pressure-tight wells, with or without T/C assemblies, and any type of special wells made to order. All are beta-gage checked for concentricity. Thermocouple wells are among thousands of accessories—all available from a single dependable source—that can help your instruments perform at their very best.



Get complete details from your nearby Honeywell field engineer, or write today for Catalog G100-5.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell
First in Control
SINCE 1906

CIRCLE 177 ON READER-SERVICE CARD

Test your BUILDING BLOCK IQ

How complete is your knowledge of digital system building blocks? Test yourself with these five questions:

1 Q. Who manufactures the highest speed digital system building blocks available today?

A. _____

2 Q. Which manufacturer utilizes a standard clamp voltage to absolutely insure the exact same voltage levels in all circuits?

A. _____

3 Q. Whose logic circuits have been evaluated time after time by independent organizations and consistently proven superior electrically to all other building blocks in use today?

A. _____

4 Q. Which manufacturer's package designs have been similarly evaluated and consistently proven superior to all other designs — in ruggedness, compactness, appearance and overall ease of handling?

A. _____

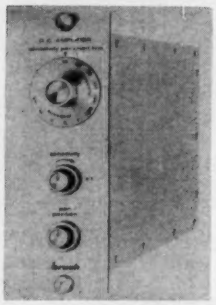
If your answer to every question was Harvey-Wells Electronics, your building block IQ is perfect . . . If not, write today for our new technical brochure plus a complete set of specification bulletins.

Harvey-WELLS ELECTRONICS INC.

14 HURON DRIVE, NATICK, MASS.

CIRCLE 178 ON READER-SERVICE CARD

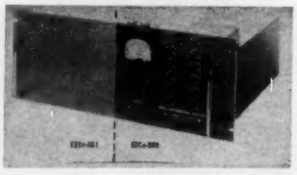
PREAMPLIFIER



New transistorized Model RD 4215 20 Very High Gain Preamplifier is chopper-stabilized and has a sensitivity of 10 μv per chart line in direct writing recorder applications. Model RD 4215 00 has a one-megohm input and a sensitivity of 100 μv per chart line. Response to a step input in both units is 90% in 2 msec.—*Brush Instruments, Div. of Clevite Corp., 37th and Perkins, Cleveland 14, Ohio.*

CIRCLE 378 ON READER-SERVICE CARD

TIMING SYSTEMS

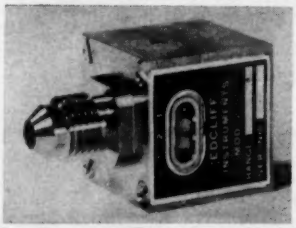


New solid-state EECO 860 Neon Distribution Amplifier accepts up to 3 pulse-width-modulated signals from a time code generator, provides 12 separate output channels with sufficient power levels to drive camera neon lines to remotely located instrumentation cameras.

New EECO 861 Relay Driver for timing signals accepts up to 7 separate pulse trains or pulse-width-modulated time codes from time code generator.—*Electronic Engineering Co. of Calif., 1601 E. Chestnut Ave., Santa Ana, Calif.*

CIRCLE 379 ON READER-SERVICE CARD

LOW-PRESSURE TRANSDUCER

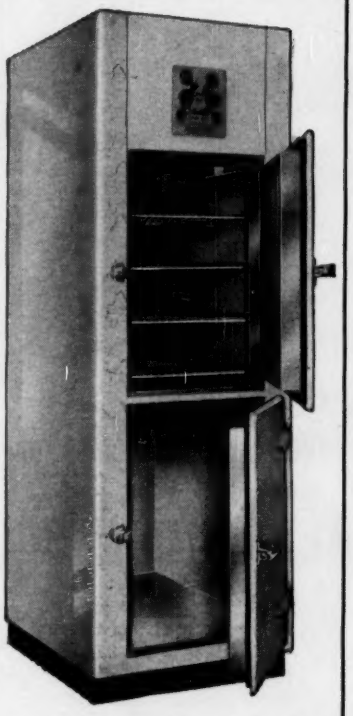


New Pressure Transducer Model 2-51 for low-pressure applications is available in operating range of 0-5 to 0-350 psia, psig or psid, with repeatability of $\pm 0.5\%$ full scale. Accuracy under vibration is $\pm 1.5\%$ max at 65 G's and 20 to 200 cps.—*Edcliff Instruments, 1711 So. Mountain Ave., Monrovia, Calif.*

CIRCLE 380 ON READER-SERVICE CARD

Anets Laboratory Cabinet

simulates all weather conditions for testing at precision controlled ranges of temperature and humidity . . .



Fully automatic electrical operation guards quality and cuts losses by determining actual results through precision controlled testing. Capacity over 17 cubic feet. Has temperature range from room to 180° F., and up to 95% relative humidity. Fully insulated. Inner construction and essential internal parts are of stainless steel. Outer cabinet finished in tough synthetic baked-on enamel. It is unequalled.

Also custom built electronic cabinets to order.

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Anets FOOD SERVING EQUIPMENT

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CIRCLE 179 ON READER-SERVICE CARD

ICS NEW LITERATURE

CONTROL

CONTROL CENTERS. 8-page Brochure F-8031-1 describes remote temperature indication, recording, and control point adjustment by electric and electronic instruments.—Barber-Colman Co., 1300 Rock St., Rockford, Ill.

CIRCLE 381 ON READER-SERVICE CARD

SUPERVISORY CONTROL SYSTEMS. 2-page bulletin "Digital Supervisory Control and Telemetering Systems," treats the subject of automatic remote control in general, as well as five specific systems in military and industrial applications.—Moore Associates, Inc., 893 American St., San Carlos, Calif.

CIRCLE 382 ON READER-SERVICE CARD

SELECTOR SYSTEMS. 8-page brochure, "Selector Systems," describes and illustrates conveyor-material-handling Control Systems including Electro and Mimic consoles.—Control Design & Fabricate, Inc., 30725 12 Mile Rd., Farmington, Mich.

CIRCLE 383 ON READER-SERVICE CARD

MAN/AUTO CONTROL STATION. 2-page Publication SRM 463.21 describes electric manual-automatic control station, Type AMA, to provide a visual check on system response.—Republic Flow Meters Co., 2240 Diversey Parkway, Chicago 47, Ill.

CIRCLE 384 ON READER-SERVICE CARD

LOOK

into the many advantages of Heuer timing instruments before you buy any other stopwatch. The exclusive Central register with 85% greater legibility and increased dial capacity will help you do a faster more accurate timing job. Free catalogue describes more than 100 standard timers. **Heuer Timer Corporation.**

441 LEXINGTON AVENUE NY 17, NY OX 7-2150.

CIRCLE 385 ON READER-SERVICE CARD

TEMPERATURE CONTROLS. 8-page Catalog MC-203 contains brief descriptions and specifications for 17 different types of temperature controls.—Fenwal Incorporated, Pleasant St., Ashland, Mass.

CIRCLE 390 ON READER-SERVICE CARD

THERMOSTATS. 2-page Bulletin 3560 covers Type GP Commercial Thermostats with ratings, ranges, tolerances and differentials, and design features.—Stevens Mfg. Co., Inc., Box 1007, Mansfield, Ohio.

CIRCLE 391 ON READER-SERVICE CARD

TEMPERATURE SENSORS. 2-page Special Product Note 140A describes surface, bulb, and open type platinum-resistance transducers for use with electronic thermometer.—Trans-Sonics, Inc., Box 328, Lexington 73, Mass.

CIRCLE 392 ON READER-SERVICE CARD

THERMOCOUPLE. 6-page brochure describes Disposable Thermocouple Lance for measuring molten steel temperatures.—Electro-Nite Engineering Co., 4418 Holmesburg Ave., Phila. 36, Pa.

CIRCLE 393 ON READER-SERVICE CARD

FORCE, WEIGHT ACCELERATION

STRAIN GAGE ACCELEROMETER. 2-page Bulletin 4203 contains description and design features of Type 4-203 Strain Gage Accelerometer including low cross axis response, small damping change with temperature, and high resonant frequency.—Consolidated Electrodynamics Corp., a Subs., of Bell & Howell, 360 Sierra Madre Villa, Pasadena, Calif.

CIRCLE 394 ON READER-SERVICE CARD

SCALE ERROR. 8-page booklet outlines causes of scale error and suggests maintenance program.—Howe Scale Co., Rutland, Vermont.

CIRCLE 395 ON READER-SERVICE CARD

DATA HANDLING

G-20 COMPUTER REPORT. 8-page report, "A Solution to the Profit Squeeze," describes how the G-20 uses multiple regression analysis and linear programming to provide manufacturing management with timely data for improved control and decision making.—Bendix Computer Div., 5630 Arbor Vitae St., Los Angeles 45, Calif.

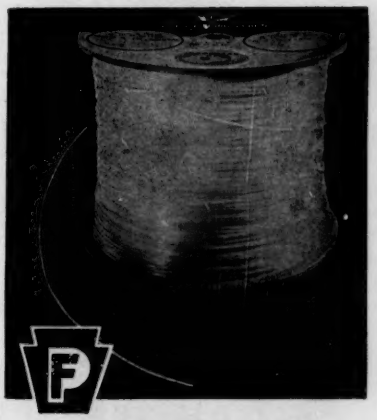
CIRCLE 396 ON READER-SERVICE CARD

DIGITAL TELEMETER SYSTEM. 4-page Bulletin GEZ-3312 describes fast, 100% accurate telemetering of kwhr readings from remote locations to central load dispatch office.—General Electric Co., Schenectady 5, N. Y.

CIRCLE 397 ON READER-SERVICE CARD

COMPUTER INSTALLATION. 8-page booklet analyzes preparation for an Electronic Data Processing System Installation.—Philco Corp., Computer Div., 3900 Welsh Rd., Willow Grove, Pa.

CIRCLE 398 ON READER-SERVICE CARD



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SPAGHETTI TUBING MADE FROM

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by Pennsylvania Fluorocarbon

To obtain outstanding results from sheathing for wires, slip-on insulation and bushings, use the unique electrical properties of spaghetti tubing made from Teflon plus the outstanding engineering and manufacturing techniques developed by Pennsylvania Fluorocarbon.

The unique electrical properties of spaghetti tubing made from Teflon include: good dielectric strength (1000-2000 volts/mil); lowest dielectric constant (2.0) and dissipation factor (0.0002) of any solid dielectric; no change of electrical properties with temperature (-25°C. to +250°C.), or frequency (60 cycles to 100 mc.); unaffected by moisture. In addition, PF Teflon is not harmed by the hot soldering iron so assembly work is speeded up considerably.

The outstanding engineering and manufacturing techniques developed by Pennsylvania Fluorocarbon include: the tailoring of Teflon with colors for identification or with modifications for improved texture and mechanical properties; stress relieving spaghetti tubing for minimum shrinkage; cleaning and 100% inspection; the manufacture of a wide range of wall thicknesses and special sizes.

Write, wire or call and let us quote on your requirements. We can provide overnight delivery of standard sizes and many special sizes at competitive prices.

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DIAPHRAGM GAUGES

for accurate pressure measurement in ounces or inches of water

Standard dials reading in inches of water, ounces, centimeters or millimeters up to 10 P.S.I. All Marshalltown diaphragm gauges are extremely sensitive and accurately measures very low pressures.

Let Marshalltown answer your gauge problems . . . write for information and prices.

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A Subsidiary of The Electric Autolite Company
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CIRCLE 181 ON READER-SERVICE CARD

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Model M-121

PORTABLE TEMPERATURE INDICATOR

for accurate measurement of temperatures between -40° F and 400° F

The MICRO-TEMP Model Series 100 and 200 Portable Temperature Indicator illustrated uses a highly sensitive thermistor as the temperature sensor. This pocket-size indicator, 2½" x 4" x 9", is battery operated, using two inexpensive penlite batteries. MICRO-TEMP uses a MARION MEDALIST meter with easy to read linear scale. Highly accurate, available with probes, MICRO-TEMP is precision built and moderately priced. Write for descriptive literature today!

Meter Mfgd. by Minneapolis-Honeywell

THERMO-PRODUCTS CO., INC.
Electronic Temperature Controls
TPC
CEDARBURG, WISCONSIN

CIRCLE 182 ON READER-SERVICE CARD

PROGRAMMED DATA PROCESSOR. 8-page Bulletin F-11 illustrates and describes features and applications of Digital Computer with solid-state logic, 100,000 additions/min, flexible input-output, etc. 10-page PDP Programming Note describes FRAP and DECAL programs.—Digital Equipment Corp., Maynard, Mass.

CIRCLE 399 ON READER-SERVICE CARD

TAPE READER. 2-page Bulletin 3.7 describes Type RA-1656 Punched Tape Reader that can read punched tape at the rate of 1500 characters/sec, and stop on character at 500 characters/sec.—Westrex Corp., Recording Equipment Dept., Litton Lndustries, 6601 Romaine St., Hollywood 38, Calif.

CIRCLE 400 ON READER-SERVICE CARD

VOLTAGE DIGITIZERS. 4-page Data Sheets for the V9-AB, a feedback voltage-to-decimal encoder; and the VR-9-AB, a high-speed, voltage-to-binary encoder, both containing a digital-to-analog converter in a feedback loop, contain applications information, general specifications for such features as weight, dimensions, electrical outputs, and temperature range, etc.—Adage, Inc., 292 Main St., Cambridge 42, Mass.

CIRCLE 401 ON READER-SERVICE CARD

LOGIC MODULES. 6-page Catalog TS-55 describes DigiBit series of transistorized digital logic packages (flip-flops, diode AND and OR gates, RC gates, inverters, etc.).—Tech Serv. Inc., 4911 College Ave., College Park, Md.

CIRCLE 402 ON READER-SERVICE CARD

RECORDERS

RECORDER. 2-page Bulletin 792-5 describes Model HR-92/93 XY recorder.—Houston Instrument Corp., Box 22234, Houston 27, Texas.

CIRCLE 403 ON READER-SERVICE CARD

AIRBORNE MAGNETIC RECORDER. 2-page Bulletin 3.3 contains specifications and description of the Westrex Type RA-1653 airborne Magnetic Recorder which records through 500-g shock.—Westrex Corp., Recording Equipment Dept., Litton Industries, 6601 Romaine St., Hollywood 38, Calif.

CIRCLE 404 ON READER-SERVICE CARD

INKING SYSTEMS. 4-page Bulletin 101 illustrates and describes Automatic Inking Systems for recorders.—Write Right Co., Box 1081, Houston 1, Tex.

CIRCLE 405 ON READER-SERVICE CARD

TESTING

LAB TEST EQUIPMENT. 8-page Bulletin Lab-200 contains specs and illustrations of Oscilloscope, pulse generator, calibrator, VT Volt-Ohmmeter, V-Ohm-Milliammeters, Plug-in Units, Temperature Indicators, etc.—Simpson Electric Co., 5200 West Kinzie St., Chicago 44, Ill.

CIRCLE 406 ON READER-SERVICE CARD

PRODUCT TESTING. 9-page brochure describes how numerical control can be used in testing manufactured products.—Designers for Industry Inc., 4241 Fulton Parkway, Cleveland 9, Ohio.

CIRCLE 407 ON READER-SERVICE CARD

Shore HARDNESS TESTING

The Shore Scleroscope for testing the hardness of metals and other materials. Accurate, rapid, completely portable, non-marring. Over 40,000 in use. Pioneer American standard since 1907.
The Shore Durometer for testing the hardness of rubber and rubber-like materials. May be used free hand or mounted on Operating Stand. Conform to ASTM D676, D1484, & D1706

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Fine-Wire Thermocouples 0.001 to 0.003 in. Rugged bodies. 10 Millisecond time constant for GAS TEMPERATURES.

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THE F&M MODEL 40 LINEAR TEMPERATURE PROGRAMMER linearly increases temperature of heating equipment or maintains it at constant temperature. 18 linear heating rates from 0.3 to 42°C/min. are provided from 0 to 500°C; adaptable to 1600°C.

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Pittsburgh 14, Pa.

CIRCLE 186 ON READER-SERVICE CARD

ELECTRICAL, ELECTRONIC INSTRUMENTS

ELECTRONIC INSTRUMENTS. Two 2-page bulletins describe and illustrate (1) Diode Recovery Tester, Model DRT-40, for recovery characteristics; and (2) Digital Resolver, Model DR14, a digital Cartesian-to-polar coordinate converter.—Computer Control Co., Inc., 983 Concord St., Framingham, Mass.

CIRCLE 408 ON READER-SERVICE CARD

PHASE ANGLE METER. 4-page bulletin describes Vectorlyzer, Type 202, which measures phase angle between two voltages.—Ad-Yu Electronics Lab., Inc., 249 Terhune Ave., Passaic, N. J.

CIRCLE 409 ON READER-SERVICE CARD

D-C COUPLED OSCILLOSCOPE. 4-page folder illustrates, describes and explains, applications of compact, low-priced lightweight Primer-Scope Mark I.—Waterman Products Co., Inc., 2445 Emerald St., Phila. 25, Pa.

CIRCLE 410 ON READER-SERVICE CARD

FREQUENCY METERS. 4-page Bulletin 700 describes, specifies, and illustrates several types of frequency meters.—PRD Electronics, Inc., 202 Tillary St., Brooklyn 1, N. Y.

CIRCLE 411 ON READER-SERVICE CARD

GAUSSMETERS. 2-page Bulletin 820 describes a 1/10 of 1% Precision Gaussmeter.—Rawson Electrical Instrument Co., Inc., 110 Potter St., Cambridge 42, Mass.

CIRCLE 412 ON READER-SERVICE CARD

ELECTRONIC INSTRUMENTS. 8-page Catalog A-26 provides short form specifications and illustrations of complete line of precision measurements instruments, Dekaline components, resistance networks and ESIAC computers.—Electro Scientific Industries (formerly Electro Measurements), 7524 S. W. Macadam Ave., Portland 19, Ore.

CIRCLE 413 ON READER-SERVICE CARD

CONTROL METERS. 12-page Fact File describes Model 2547-1 and -2 contactless electronic control meters incorporating D'Arsonval Meter movement and shield.—International Instruments, Inc., 88 Marsh Hill Rd., Orange, Conn.

CIRCLE 414 ON READER-SERVICE CARD

MISCELLANEOUS

IMPULSE COUNTER. 12-page Bulletin E62 describes SODECO Impulse Counters and gives technical data.—Landis & Gyr. Inc., 45 West 45th St., New York 36, N. Y.

CIRCLE 415 ON READER-SERVICE CARD

VISCOSITY MEASUREMENT. 2-page Bulletin V-1240 describes Viscometer Receivers for use with Norcross Viscometer measuring elements.—Norcross Corp., 247 Newtonville Ave., Newton 58, Mass.

CIRCLE 416 ON READER-SERVICE CARD

NUCLEAR DENSITY GAGING. 6-page Bulletin No. 105-C describes details of basic systems employing nuclear gages for controlling specific gravity or density and liquid or interface levels.—Ohmart Corp., 2236 Bogen St., Cincinnati 22, Ohio.

CIRCLE 417 ON READER-SERVICE CARD

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Heavy-Duty 2 & 3 Dimensional Engraver

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Fine Routing Work
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Making Small Dies and Molds

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1. Six Reduction Ratios—From 1.5:1 to 4:1.
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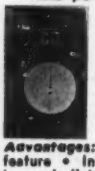
Model HT-12 Four-Range Tachometer
Centrifugal tachometer that measures revolutions per minute and surface speeds.



TOTAL RANGE: 90-12,000 RPM
1st — 90-360 RPM
2nd — 300-1200 RPM
3rd — 900-3600 RPM
4th — 3000-12000 RPM
Feet per minute—one half the dial reading with use of 6" disc wheel.

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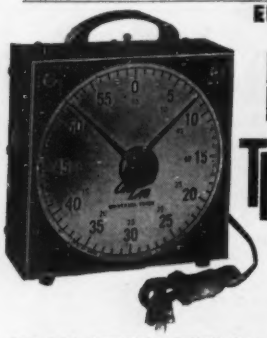

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VOLTAGE SUPPLY. 2-page Spec PS100-1 describes Models BS-1 and BS(TC)-1 Recorder Bridge Voltage Supply for replacing short-life dry cells in potentiometers; 2-page Spec PS100-2 describes Constant Voltage Supply for replacing drifting dry and wet cells normally used with potentiometers.—Dynage, Inc., 390 Capitol Ave., Hartford, Conn.

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AUTOMATIC COLOR MEASUREMENT. Two 4-page brochures describe the new Green-Bartlett technique of high-speed fully-automatic color measurement.—Allied Research Associates, Inc., Colorimetry Div., 43 Leon St., Boston 15, Mass.

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ADAPTER FITTINGS. 16-page Catalog covers pipe-thread and straight-thread adapters for tubing system connections.—Parker Fittings & Hose Div., Parker-Hannifin Corp., 17325 Euclid Ave., Cleveland 12, Ohio.

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SWITCHES. 2-page Bulletin E9 describes Deltadyne externally-adjustable and differential pressure switches.—PALL Corporation, 30 Sea Cliff Ave., Glen Cove, N. Y.

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RESISTOR NOISE. 4-page brochure discusses theory and measurement of resistor noise.—Quan-Tech Laboratories, Inc., Boonton, N. J.

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RACK CABINET. 4-page brochure illustrates and describes standardized Rack Cabinet FT192.—Falstron Co., 208 Falstrom Court, Passaic, N. J.

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DISPLACEMENT FOLLOWER. 4-page brochure describes and illustrates Model 701 Displacement Follower with standpower supply, lens, and static calibrator.—Optron Corp., 335 So. Salinas St., Santa Barbara, Calif.

CIRCLE 424 ON READER-SERVICE CARD

SELECTIVE TONE SIGNALING. 8-page Catalog 563 describes systems and components for selective tone signaling.—Stevens-Arnold Inc., 7 Elkins St., South Boston 27, Mass.

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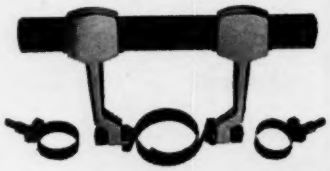

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CIRCLE 426 ON READER-SERVICE CARD

INDUSTRY NEWS

ESTERLINE ANGUS INSTRUMENT CO. announces that *Hugh C. Cameron* has been appointed sales manager.

H. C. Cameron

J. E. Gambrill

A. E. Lawson

GOW-MAC INSTRUMENT COMPANY has appointed *Alexander E. Lawson, Jr.* to the vice-presidency.

MOORE PRODUCTS CO. announces that *James E. Gambrill* has been appointed general sales manager.

SANBORN COMPANY announces election of *James L. Jenks, Jr.* as chairman of the board of directors, *George A. Sanderson* as vice chairman, and *Alfred E. Lonnberg,* as president.

MANNING, MAXWELL & MOORE announces the following appointments for the new Gauge & Instrument Division formed from the former Consolidated Ashcroft

F. J. Murphy

M. S. Palmer

E. M. Dederer

L. F. Kirby

N. C. Rardon

Hancock Division: *F. J. Murphy,* assistant general sales sales manager; *M. S. Palmer,* director of O.E.M. marketing; *E. M. Dederer,* assistant director of O.E.M. marketing; *L. F. Kirby,* product manager for "American" industrial instruments; and *N. C. Rardon,* mid-western (Chicago) district manager.

WEKSLER INSTRUMENTS CORPORATION, according to E. P. Dobrin, president, has embarked on an expansion program to provide closer liaison between field sales personnel and company management as well as improved customer services. An additional building is in ground-breaking stage, which will double Weksler's production capability.

FOR YOUR R and D

NEW THERMOCOUPLE TEST KIT

$12.95

HARCO Thrift/Therm Test Kit is exactly right for your R & D work. These four types of Thermocouples handle *virtually every* temperature sensing application. Thrift/Therms are highly accurate, precision-made, miniaturized Thermocouples, fast to respond to the slightest temperature changes. You get: a spring-loaded unit for internal surface temperatures or gases; a probe-type HARCO Sheathed Thermocouple for use with liquids and gases — (will handle 3500 psi) and a HARCO Sheathed Thermocouple with an exposed junction for liquids and gases where fast response is needed.

Send P.O. or Check and try these precision Thermocouples for reliability and adaptability in your own lab.
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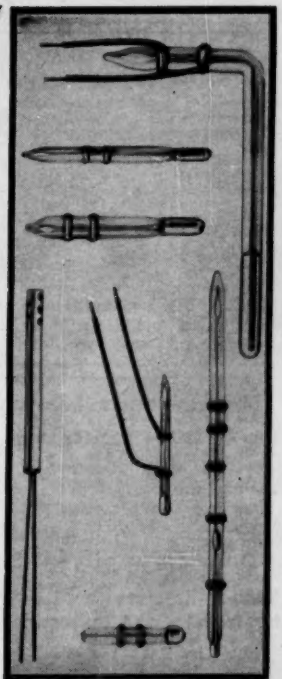
Tiny PRINCO Thermostats Control Temperature to .05°C



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